DOCUMENT RESUME

ED 213 588 SE 036 240

AUTHOR Clarkson, Philip, Ed.
TITLE Research in Mathematics Education in Papua New Guinea, 1981.
INSTITUTION Papua New Guinea Univ. of Technology, Lae.
PUB DATE 81
NOTE 206p.; Proceedings of the Mathematics Education Conference (1st, Mathematics Education Centre, Papua New Guinea Univ. of Technology, Lae, May, 1981).
AVAILABLE FROM The Director, Mathematics Education Centre, Papua New Guinea Univ. of Technology, P.O. Box 793, Lae, Morobe Province, Papua New Guinea (no price quoted).

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS *Curriculum Development; Educational Research; Elementary Secondary Education; Higher Education; Instruction; Learning Theories; Mathematics Achievement; *Mathematics Curriculum; *Mathematics Education; *Mathematics Instruction; Student Attitudes
IDENTIFIERS *Mathematics Education Research; *Papua New Guinea

ABSTRACT

This document contains the following titles: 1) Students' Use of Diagrams and Visuality in Mathematics; 2) Papua New Guinea University Student Attitudes to Mathematics; 3) Research on the Teaching of Problem Solving at the Papua New Guinea University of Technology: Retrospect and Prospect; 4) Adult Numeracy with a Calculator: Some Problems; 5) A Test of Measurement-- Or Is It; 6) Solving Word Problems in a Second Language and Reading Proficiency; 7) Nurses and Mathematics; 8) Language and Mathematics at Tertiary Level; 9) The Role of Mathematics Education Research in Papua New Guinea 1981: The Constraints and the Priorities; 10) Computer Oriented Cognitive Process Models Related to Mathematical Thinking; 11) The Use of Numerical Filters as an Aid to the Solution of Algebraic Problems: A Proposed Project; 12) An Investigation of the Mathematics Education of Nurses-In-Training in Papua New Guinea; 13) A Proposed Categorization System for Students' Errors in Mathematics; 14) The Performance of National High School Students at the University; 15) Language and Mathematics Education: An International Perspective; 16) Community School Mathematics Teaching and Curriculum Innovation in Papua New Guinea; and 17) Standards in Mathematics, a Defeatist Point of View. (MP)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED213588

RESEARCH in MATHEMATICS EDUCATION in Papua New Guinea

1981

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION

PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

P.Clarkson (ed)

SE 036 240

THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

THE MATHEMATICS EDUCATION CENTRE

The Mathematics Education Centre is a successor of the Mathematics Learning Project set up in 1972 with the aid of the Nuffield Foundation, the R.E. Ross Trust of Victoria and other philanthropic bodies. The establishment of the Centre was made possible with aid from the British Council over the period 1978 to 1979. From 1980 the Centre has been completely funded by the University of Technology.

The brief of the Mathematics Education Centre includes a substantial commitment to educational research at all levels of the education system. In addition the Centre provides advice and assistance to tertiary level institutions, the National High Schools, the Technical Division of the Education Department and to schools in the Morobe Province.

Research projects are undertaken by members of both the Centre and the Mathematics Department of the University. Visitors from overseas are also encouraged to work at the Centre on specific projects. This occasional series reports on the work conducted by resident staff and the visitors to the Centre.

Copies of M.E.C. reports and further information about the Centre is available from :-

The Director,
Mathematics Education Centre,
Papua New Guinea University of Technology,
P.O. Box 793,
LAE. MOROBE PROVINCE.
Papua New Guinea.

RESEARCH IN MATHEMATICS EDUCATION

IN

PAPUA NEW GUINEA:

1981

EDITED BY

PHILIP CLARKSON

PROCEEDINGS OF THE FIRST
MATHEMATICS EDUCATION CONFERENCE,
MATHEMATICS EDUCATION CENTRE,
LAE,
MAY, 1981.

c Mathematics Education Centre
1981

Published and printed by

Mathematics Education Centre Press,
University of Technology,
P.O. Box 793,
Lae.
Papua New Guinea.

CONTENTS

Students Use of Diagrams and Visuality in Mathematics
Phillip Clarkson 1

Papua New Guinea University Student Attitudes to Mathematics
Phillip Clarkson and Helen Whippy 21

Research on the Teaching of Problem Solving at the Papua New Guinea University of Technology: Retrospect and Prospect.
Lilia S. Dube 38

Adult Numeracy with a Calculator: Some Problems
Allen Edwards 43

A Test of Measurement - Or is it?
Harold R. Fredericks 52

Solving Word Problems in a Second Language and Reading Proficiency
Peter Jones 58

Nurses and Mathematics
Susan Pirie 75

Language and Mathematics at Tertiary Level
Martin Reed 80

The Role of Mathematics Education Research in Papua New Guinea 1981: The Constraints and the Priorities
R.E. Roberts 97

Computer Oriented Cognitive Process Models Related to Mathematical Thinking
Rod Seldon 108

The Use of Numberical Filters as an Aid to the Solution of Algebraic Problems: A Proposed Project
Mike Siford 118

An Investigation of the Mathematics Education of Nurses-In-Training in Papua New Guinea
Peter Sullivan 121

A Proposed Categorization System for Students' Errors in Mathematics
Wilson Tovirika 129

The Performance of National High School Students at University
C.W. Wilkins 146

Language and Mathematics Education: An International Perspective
Bryan Wilson 154

Community School Mathematics Teaching and Curriculum Innovation in Papua New Guinea
Randall Souviney 167

Standards in Mathematics, A Defeatist Point of View

L.Ros

196

STUDENTS USE OF DIAGRAMS AND VISUALITY IN MATHEMATICS

Philip Clarkson
M.E.C.

Many students in school do not reach their full potential as learners of mathematics because they can not make full use of the written material on which most mathematics courses depend. A number of writers have drawn attention to the particular difficulties which students have with reading mathematics. For example, words that have special meanings in mathematics classrooms (half, group, imaginary); words which only have meaning in mathematical contexts (hypotenuse); sentences which refer back to other statements thus making the text itself the object of the text; symbolic language; and finally diagrams have all been noted as causing learning problems. Both symbolic language and diagrams depend a good deal on students' spatial ability. In symbolic language the actual position of the symbols in relation to one another often carries much of the meaning intended by the short hand. For example;

3^2 32 (3,2) f_2^3 3×2

all mean very different things, although the principal symbols are the '3' and '2'. However, in this paper it is the diagrams with which students deal that will occupy our attention.

For those of us who studied Euclidian geometry at school, the method for 'proving' theorms was straightforward. You followed the headings or a similar set;

Required to prove
Diagram
Constructions
Instruments
Proof
(and if you succeeded)
Q.E.D.

These headings were fairly common in Australian schools in the 1950s. It did not really matter that the meaning of the schema was not really clear, the path was there to be

followed by rote. So the appropriate diagram was looked at and a construction attemptedif necessary. Oft was the teacher's comment to any student who could not see what to do;"Look at the diagram lad, look at the diagram!"

It is not only in geometry that diagrams are believed to be efficacious. Few topics in school texts are not without their attendent diagrams. Text book writers, mathematics teachers in general, and lecturers in mathematics education courses all believe that the visual presentation of ideas help students in their understanding. In writing student material, it becomes a conscious habit to include a diagram as a further explanation when the written material becomes involved, or even to let the diagram stand alone in an attempt to reduce the amount of written explanation. However this assumes that students will recognise the importance of diagrams as integral or useful parts of an explanation, and secondly, be able to decipher the information contained in them. This second point is also relevant when the diagram itself is the object of study, as in curve sketching.

A common definition of spatial ability is 'the ability to visualize and manipulate appropriate mental images'. Clearly three aspects of the ability are evident in this definition; visual imagery, mental rotation and mental transformation. Visual imagery means here the ability required to form appropriate mental images given a verbal or written stimulus, or if a pictorial stimulus is given, to isolate out from background distractions the required image. Once having formed the appropriate mental image, it is hoped students will be able to analyse the inherent relationships within the image. If only these abilities are required, static spatial ability is called on. Manipulative spatial ability is needed for any transformation or rotation of the image. Thus if students are to be able to use the diagramatic material in texts or worksheets, this spatial ability must be at such a level where at least they can analyse diagrams.F.Ausburn

and L.Ausburn (1981) in reviewing relevant literature concluded that the process can be taught. Bishop (1978) after a small, intensive case study, using students from the PNG University of Technology, concluded that the teaching process in Papua New Guinea should relate to the strengths of the students. He suggested that one such strength was their capabilities of thinking in the visual mode.

The present project, of which this paper is the first report, seeks to build on this and other recent research in spatial ability carried out at the Mathematics Education Centre. The long term object of the project is to relate this research to the text material students use, and in particular the visual impact of the material.

The aim of this first study of the project was to explore the preferred mode of processing mathematical information used by year 10 students at Provincial High Schools in an urban area of Papua New Guinea. The instruments used in this study categorised subjects as those who preferred to process mathematical information by verbal-logical means, as opposed to those who preferred visual processes.

This study's instruments are based on one developed at Monash University in 1979 by S.Suwarsono for a doctoral thesis. It consisted of two parts; the first a series of thirty mathematical word problems, and the second was a questionnaire which contained written descriptions of

different methods commonly used by students who had tried to solve the problems in part 1. Questions ranged from 'very easy' to 'moderately difficult' with 'very difficult' questions being avoided. Diagrams, or suggestions that diagrams should be drawn were not included in these questions. Since a variety of methods were expected to be used by students attempting the problems, the descriptions in part 2 covered visual as well as verbal-logical methods. Suwarsono administered the questions to 200, year 7 students. He obtained a score for part 2 of the instrument using the following criteria for each problem:

+2 if the correct answer was given on part 1, and the reasoning was based on a diagram drawn by the student, or on a visual image constructed by the student.

+1 if an incorrect answer was given on part 1 and the reasoning was based on a diagram or visual image.

0 if no answer was given or the student could not decide on which method was used.

-1 if an incorrect answer was given on part 1 and the reasoning was of a verbal-logical method which did not involve the construction of a diagram or visual image.

-2 if the correct answer was given on part 1 and the reasoning was of a verbal-logical type.

Thus he obtained scores which ranged from -60 to +60. Using an extension of the Rasch model, the word problems were placed on an assumed 'analytical-visual' dimension, and this also enabled the measurement of students' preferences for visual or verbal-logical methods on the same 'analytical-visuality' scale.

Lean and Clements (1980) have given a more detailed description of Suwarsono's work in their introduction to a study in which they used a modified form of this instrument with students attending the PNG University of

Technology. Their data supported Suwarsono's contention that the instrument did measure a person's preferred mode of processing mathematical information, and that there did appear to be a distinct cognitive trait associated with mathematical processing.

Although the Lean and Clements study is valuable, it can be criticised on two counts. The questions which were used may well have been too easy for the students. The mean score for their sample was 11.1 out of 15 with a standard deviation of 2.13. (Unlike Suwarsono's original instrument, Lean and Clements only used 15 questions, not 30.) They point out in criticising other studies which used 'very difficult' questions that students may only be guessing, and hence the methods they use for such guesses may well be unreliable. If a reliable score is to be obtained, then students must have confidence in their ability to solve the problem correctly. Such an argument is hard to fault. However if the problems are too easy, they may well be regarded as routine problems by students, and hence more efficiently dealt with using verbal-logical methods. It may well be that of the students Lean and Clements worked with, some may well have preferred visual methods when faced with harder problems. They were never forced into this mode of thinking however by the set of problems used. A parallel can be drawn in Piagetian studies. In such studies there is always the problem of knowing whether a student who is using concrete methods is capable of formal thought, but is not being pushed enough to use it.

A second criticism of the Lean and Clements study was their deliberate avoidance of diagrams in the questions. The argument used for omitting such questions was that if diagrams were given, this would bias the preferred methods to the visual end of the scale. There appears to be some truth in this, especially if questions deliberately

ask for diagrams to be obvious. However, it could equally be argued that by avoiding diagrams altogether, students may well be biased to the verbal-logical end of the scale, since the stimulus is wholly written. If results from such an instrument are to be generalizable to the real life of the student, then with the predominance of diagrams in students' tests and worksheets such an argument needs to be examined.

AIMS and SUBJECTS

The present study sort information on two principal questions:

(i) Does the provision of diagrams effect students' preferences in processing mathematical information?

(ii) Is a student's preference for one type of thinking consistent over time and with different styles of questions?

To investigate these questions six year 10 classes from three Provincial High School in Lae were tested. Provincial High Schools consist of classes in years 7 to 10. The majority of the students are boarders, and unlike western schools, the students age range within any one year will vary by up to seven years. The centrally imposed syllabus is fairly strictly adhered to, and at the time of this study all classes were studying ratio after dealing with topics of numbers and directed numbers in previous weeks. Noting the current areas of study for PNG students may well be very important when investigating mattersrelated to spatial ability. Bishop (1978) in an earlier study noted that Papua New Guinea students "seemed able to visualize well those stimuli which they were specifically asked to remember or which were very familiar to them." (p. 34) It would be interesting to test students on their methods of processing mathematical information while they were studying a spatially oriented topic, or using spatially oriented methods of leaving.

For reasons developed later, the six classes were split into three pairs and will be referred to as groups A, B and C.

INSTRUMENTS

The instruments were to be of the same type as that used by Suwarsono, Lean and Clements. In working with year 10 students a set of problems of appropriate difficulty had to be selected. One of the unavoidable, compounding factors in any work using written problems with Papua New Guinea students is their difficulty with reading mathematics. This leads to lack of understanding and a far greater amount of time taken to complete such problems, when compared to Western students. (Jones, 1981) A pilot study was therefore mounted to devise appropriate instruments.

The ten most straight-forward questions used by Lean and Clements were selected, and diagrams prepared for each. The diagrams were designed to be suggestive, but would need to be acted by the student for any use to be made of them. Figure 1 illustrates this point. The written questions were not altered in any way, and thus made no specific reference to the diagram. Thus two instruments were constructed; Test W the questions without diagrams, and Test D the questions with diagrams. In putting the diagrams in close proximity to the question without any overt direction to use them, the author was mirroring what often happens in text books.

Altogether there are 8 tables in a house. Some of them have four legs and others have three legs. Altogether they have 27 legs. How many tables are there with four legs?

Figure 1: An illustrative question from Test D.

Students in group A were randomly assigned either Test W or D. They were asked to complete them and then fill out the questionnaire which Lean and Clement had used. Although fifty minutes was allocated for solving the ten problems, clearly students needed far longer.

In filling out the questionnaire, the author found it best to read through it with the students, thus overcoming some of their reading problems, and answering any clarifying questions at the same time. After marking the questions, the mean average was found to be for Test W, 3.4 and for Test D, 3.9. The low figures were undoubtedly a combination of too much reading in the questions, and not enough time to complete them. Therefore the five easiest questions (35% or more correct) were selected for the final tests. It was found that the same five questions were easiest on both tests. The author, after analysing these five questions was satisfied that they still gave a range of solutions, both verbal - logical and visual. It was anticipated that using these five questions, a range of methods would be used, the questions would be of appropriate difficulty and novel, and students would have adequate time to complete them in the forty minutes available. Two scores were generated for each test; a problem solving score obtained from part 1, referred to as the P.S.S. which ranged from 0 to 5, and a analytic - visual score obtained from part 7, referred to as the A-V.S, which ranged from -10 to +10.

THE EXPERIMENTAL STUDY

The author met with groups B and C on two occassions with two weeks between the meetings. During the first meetings, Test W and D were randomly assigned to the students. The second meeting with group B was a retest situation with students assigned the same test as they had the first time. With group C, the retest took the form of assigning students with the alternative tests.

Effect of Diagrams

To investigate the effect of diagrams on students preferences for processing mathematical information, the scores of students who completed Test W in groups B and C were combined, and likewise for those who completed Test D. Before comparing the analytic-visual score (A.V.S) the problem solving score(P.S.S.) needed to be compared since A.V.S. is dependent on P.S.S. Thus any variation in A.V.S. may simply be reflecting a variation in P.S.S. Table 1 shows the comparison of the means of P.S.S. at the first meeting.

	N	$\bar{X}$	S.D.	t
Test W	73	2.89	1.21	0.25
Test D	75	2.84	1.22	

Table 1: Comparison of P.S.S. for group B+C at first meeting.

A t-Test for difference between means on independent samples indicated no significant differences. Thus it can be concluded that the diagrams made no difference to difficulty and hence the A-V.S. could be compared. Table 2 shows the comparison of the means of A.V.S. at the first meeting.

	N	$\bar{X}$	S.D.	t
Test W	73	-1.27	3.66	1.22
Test D	73	-2.02	3.80	

Table 2: Comparison of A-V.S. for group B+C at first meeting.

Again there was no significant difference. Hence it can be assumed that the presence or absence of these diagrams for these questions had no effect on students' preference for processing mathematical information.

Consistency of Thinking.

The question of consistency of thinking was broken into two parts. First taking time as the only variable, a two week period, and secondly time and type of question. Students in Group B sat the same test on both occasions. Before comparing the A-V.S., the P.S.S. needed to be considered. Table 3 shows the comparision of means for P.S.S.

	N	$\bar{X}$	S.D.	t
Test W				
Pre-test	35	2.86	1.06	3.66*
Post-test	35	3.77	1.06	
Test D				
Pre-test	32	2.73	0.67	3.67*
Post-test	32	3.55	1.10	

*significant at 0.001 level

Table 3: Comparison of P.S.S. for group B on Tests W and D.

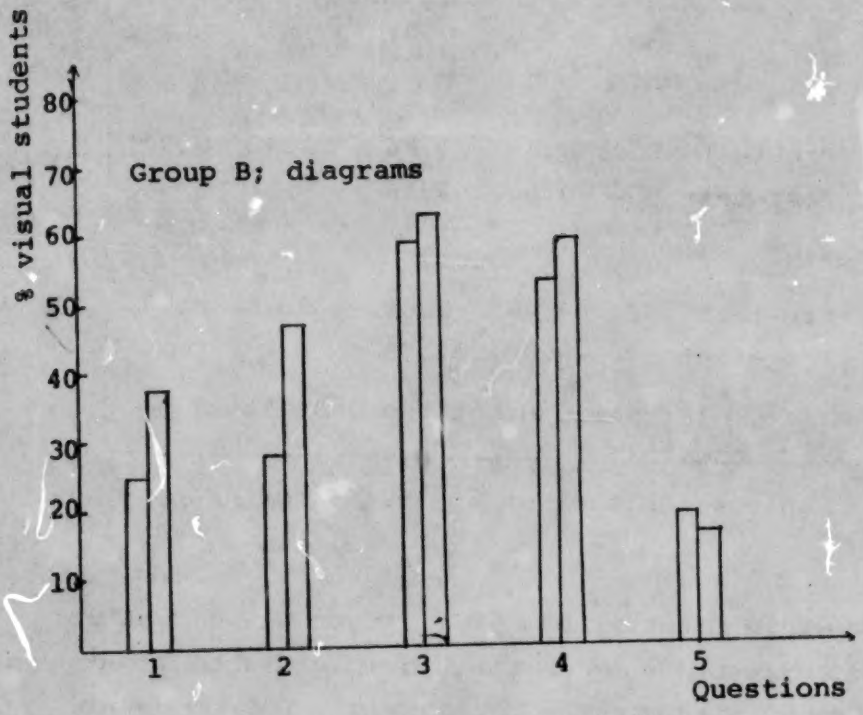
Clearly the students' improvement on the tests was both statistically and educationally significant. In one way this is encouraging, recognizing that Papua New Guinea students find such problems difficult (Sullivan, 1981). For this study it caused a difficulty in that A-V.S. depended in part on the P.S.S.. However, Suwarsono's decision to allocate an extra $\pm$ 1 mark, depending on the correctness of an answer was based on the hypothesis that for students obtaining a correct response implied they would be more confident that the methods they used were appropriate. The author's confidence in this hypothesis is not so high after interviewing some students who participated in this study. Jones (1981) has also commented on misplaced confidence of Papua New Guinea students. Therefore it appeared appropriate to simply allocate a score of +1 for a visual response, -1 for a negative response and 0 for a response where there was insufficient informaton for a decision to be made. The new scale will be shown as A-V.S' and has a range of -5 to +5. When such a system was applied, a similar pattern of scores resulted.

	N	$\bar{X}$	S.D.	t	r
Test W					
Pre-test	35	-0.09	1.86	1.42	0.37*
Post-test	35	0.64	3.16		
Test D					
Pre-test	32	-0.44	2.58	0.79	0.37*
Post-test	32	-0.03	2.58		

*significant at the 0.05 level

Table 4: Comparison of A-V.S! for group B.

Table 4 shows the comparison of A-V.S.' It can be seen that there was no difference in the mean scores indicating that the groups as a whole did not change their mode of processing. The correlation coefficient is clearly greater than zero indicating a definite positive association, but is still quite small. Thus it can be concluded that there is only a small preference for students to be consistent in their manner of processing mathematical information whether diagrams are present or not. This anomalous situation where there is no change in the group's pattern of processing, but individuals vary their methods can be explained by looking at the change in percentage of students using a visual processing methods for each question. This information is shown graphically in Figure 2.



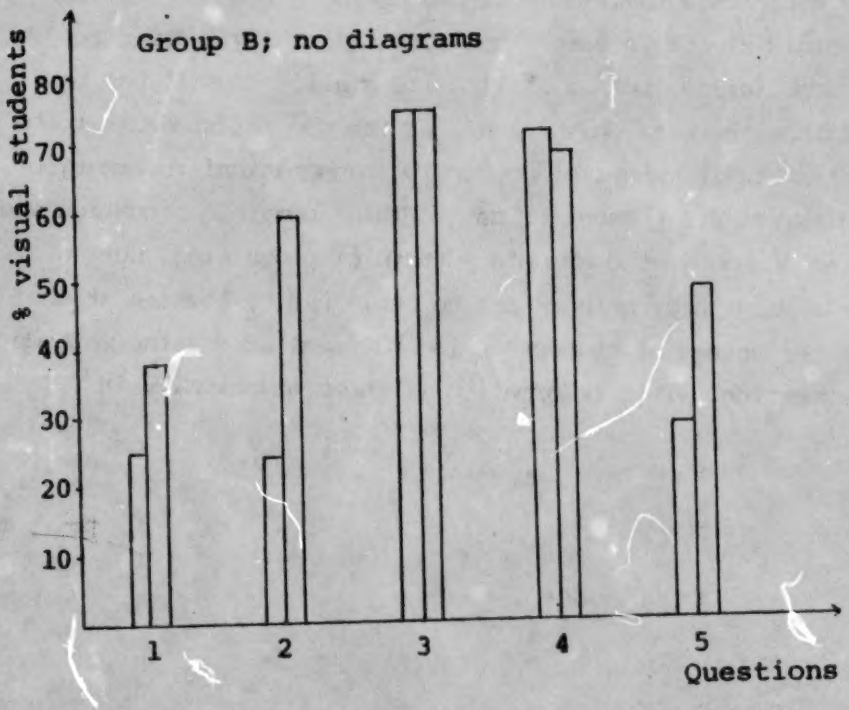


Figure 2: Comparison of percentage of students using visual processing methods for each question. NOTE: Left hand column shows pre-test results, right hand column shows post-test results.

There seems to have been a disproportionate increase in visual methods for some questions compared with others but not enough to alter the groups' averages significantly. Those questions that were processed in the same way were questions which most students processed visually to begin with. For the group that had no diagrams on their question paper, the increase on some questions is more noticable. Perhaps while reviewing the pre-test, these students were made aware of alterative processing methods which they tried in the post-test. A similar pattern to that of group B eventuated with group C scores. Table 5 shows that again there was a statistical and educational improvement in scores on the tests which could be designated as a practice effect. Therefore the A-V.S.' scale was used.

	N	$\bar{X}$	S.D.	t
Pre-test (Test W)	36	2.94	1.33	4.99*
Post-test (Test D)	36	4.19	0.75	
Pre-test (Test D)	39	3.05	0.62	3.78*
Post-test (Test W)	39	3.85	1.06	

*significant at the 0.001 level

Table 5: Comparison of P.S.S. for group C.

Table 6 again shows that although the group means for the A-V.S.' did not alter, the correlation coefficient was not significantly different to zero.

	N	$\bar{X}$	S.D.	t	r
Pre-test (Test W)	36	-1.00	2.29	1.82	0.28
Post-test (Test D)	36	0.06	2.97		
Pre-test (Test D)	39	-1.46	2.10	1.40	-0.03
Post-test (Test W)	39	-0.41	2.96		

Table 6: Comparison of A-V.S. for group C.

Once again the conclusion can be drawn that although the groups overall processing of the mathematical items did not alter, there was even less consistency with individuals, when the presentation of items was altered.

In examining individual questions (see Figure 3) it can be seen that there is a greater tendency for students to use visual processing for some questions during the post test than the pre-test, although this trend is not great enough to effect the overall figures.

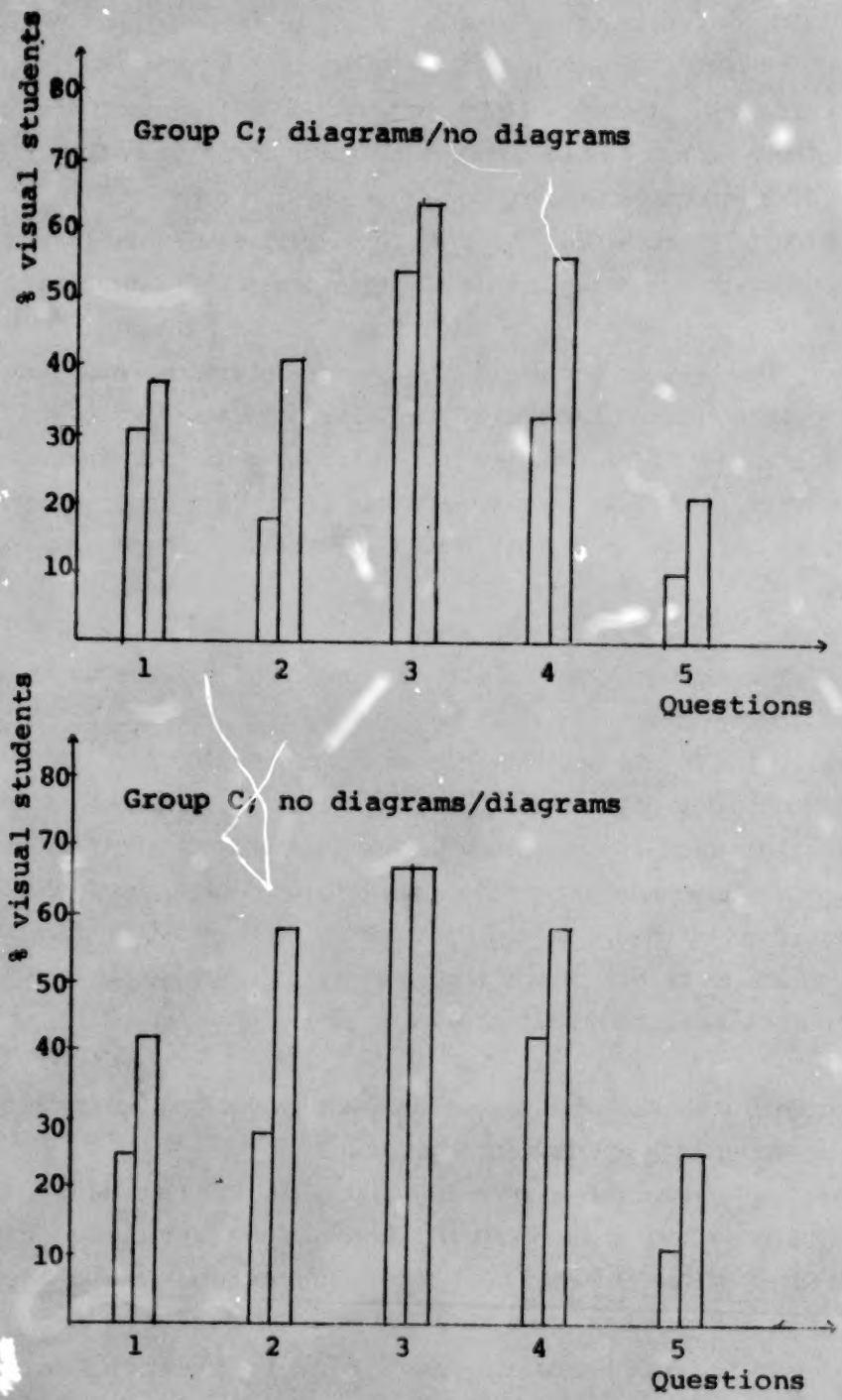


Figure 3: Comparison of percentage of students using visual processing methods for each question. NOTE: Left hand column shows pre-test results, right hand column shows post-test results.

DISCUSSION

It should be recognized that this study is in the nature of a probing exercise. A potential problem at the heart of the study is the instruments used. It may well be that with only five questions to answer, these do not sample enough situations for a generalized measure of a student's preference for processing mathematical information to be obtained. The reason only five were used was to keep the testing situation within the time available; an example of the perennial problem of trying to conduct research in naturalistic settings. However, on the basis of informal interviews with some students who completed the tests, the author is fairly confident that the instruments did provide reasonable measures of this dimension. This factor will clearly need to be followed up in a later study. In summarizing the results of this study, a number of conjectures will be stated.

1. The provision of diagrams will not necessarily alter the difficulty of material. It has been a long held belief of curriculum developers that the provision of diagrams will automatically help students solve problems. The diagrams in the questions used in this study were only linked by their close approximation to the written question, and not by any specific reference to them. It could be conjectured then that for diagrams to be effective, they need to be perceived by the students as being an integral part of the question.

2. The mere presence of diagrams does not promote visual methods of processing mathematical information.
   Lean and Clements in commenting on a study by Moses (1977), criticized her use of questions which asked students to draw diagrams. This, they suggested, would bias any measure of a visual-analytic dimension. In attempting to avoid the use of overt prompting of visual methods in this study, diagrams were used which hinted at a visual approach. Results indicated that these did not influence the students preferences.

3. Students' preferences for processing mathematical information is not consistent, and can be altered purposefully under certain conditions. The results after a two weeks interval tend to indicate that again the mere presence of diagrams did not alter a student's method of processing the mathematical information, but the discussion of the pre-test made them aware of the possible uses of the diagrams. It should be emphasized that the discussion did not encourage students to use the visual methods; the students were not told that there would be a retest. Clearly the students saw the possibilities themselves. It was noticable that during the discussion of the pre-test with all groups, comments from students indicated a general lack of appreciation of the variety of ways in which the problems could be solved.

4. The students have a capacity for both visual and analytic thinking. Although care must be taken in talking of any absolute preference of visual compared with analytic thinking of these students, it is quite clear that the students were quite capable of both. Absolute comparisons can not be made because there may not have been enough variety of questions.

CONCLUSION

After studying community school children in Papua New Guinea, Clements and Lean (1980) concluded that although these children rely upon visual memory in the lower years of schooling, these is a progressive decrease in the use of visual processing by successful students as they proceed through the school. This progression seems to climax by the time students enter tertiary institutions since Lean and Clements (1980) concluded from another study that verbal-logical reasoners have better success on conventional mathematical tests. This present study shows that year 10 students are quite capable of both

modes of thought. However, from this data no comment can be made as to which thinkers perform better at mathematics. What can be said, is that the mere presence of diagrams does not influence thinking, nor does it lessen the difficulty of questions. Far more explicit methods need to be used to tie the diagrams into the text if students are to use the information contained in them. It may well be therefore that the trend of superiority that Lean and Clements claim for analytic thinkers is a reflection of the material which they deal with on mathematical tests, and the styles of teaching to which students are subjected. It is rare for teachers in schools (and perhaps universities) to highlight alternative ways of handling problems, and rarer still for the alternative method to be based on visual processing. The driving aim normally is for students to memorize the algorithm. Hence it is no surprise to find students who have succeeded, prefering the method of learning which their teachers emphasize. However, if students can think visually, perhaps this option should be opened to them. This study has shown that even a general discussion of alternatives, which in no way set out to purposefully influence students, did seem to lead to individuals using a different method on two seperate occasions. It may well be that students on the second occasion were partially freed from the constraints of their classroom experience and started to respond more naturally to the problem. If this hypothesis was found to be correct, an approach to teaching which analysed various solutions of problem

situations may well be rewarded by students considering alternative potential solutions, and choosing an appropriate one for them.

A final problem which needs to be examined in a later study is to what extent do students use visual and analytic methods in tandem or simultaneously on the one problem. The questions in the instruments of this study have assumed that each solution to a question could be rated as visual or analytic. There was some suggestion in discussion with students that for one or two of the questions it was important for the students to 'visually orientate' themselves, and then actually process the information analytically. This needs to be teased out by further interwiews.

REFERENCES

Ausburn F. and Ausburn L. 'Perception, Imagery and Education', *Mathematics Education Centre Report 17*, Papua New Guinea University of Technology, 1981.

Bishop A. J. 'Spatial Abilities in a Papua New Guinea Content' *Mathematics Education Centre Report 2*, Papua New Guinea University of Technology, 1980.

Clements M.A. and Lean G.A. Influences on Mathematical Learning in Papua New Guinea: Some Cross - Cultural Perspectives, *Mathematics Education Centre Report 13* Papua New Guinea University of Technology, 1980.

Jones P. 'Mathematical Language and the Learning of Mathematics in Papua New Guinea', *Mathematics Education Centre Report 16*, Papua New Guinea University of Technology, 1981.

Lean G.A., Clements M.A. 'Spatial Ability, Visual Imagency and Mathematical Performance', *Mathematics Education Centre Report 10*, Papua New Guinea University of Technology, 1980.

Moses B.E. 'The Nature of Spatial ability and its Relationship to Mathematical Problem Solving', unpublished doctoral dissertation, Indiana University, 1977.

Sullivan P. 'The Standards Debate: An Alternative Approach', *Mathematics Education Centre Report 15*, Papua New Guinea University of Technology, 1981.

PAPUA NEW GUINEA UNIVERSITY STUDENT ATTITUDES TO MATHEMATICS

PHILIP CLARKSON AND HELEN WHIPPY

MATHEMATICS EDUCATION CENTRE & MATHEMATICS DEPARTMENT

PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

There have been many studies on students' attitudes to mathematics, mainly probing the relationship between attitude and achievement. Although many teachers believe it is important for students to have a positive attitude to this subject if they are to do well, research has tended to show that there is little relationship between positive attitudes and high achievement (Aitkens, 1970). The authors wish to take a different tack.

It seems important to the authors that students, especially those in a tertiary technological institution, should develop feelings of success and encouragement whilst pursuing the study of mathematics for their own sake, rather than linking such an attitude to an ultimate goal of achievement. Students should learn to 'appreciate' mathematics, where appreciation includes both enjoyment of the subject and respect for its utility. Thus it seemed useful to probe 'attitudes' as the fundamental aim, rather than attitudes linked to achievement.

A second reason for this aim is that a lecture room is a place where people interact, with (hopefully) the common pursuit of helping students more fully understand a particular discipline. Because of this interaction, it would seem probable that if the lecturer and students had vastly different perceptions of the task and the discipline, useful communication would be hard to come by. Thus it seemed to the authors useful to explore on the one hand student's perceptions, and if there is time, lecturers perceptions of this interaction.

This paper outlines a project set up to investigate this area and reports on some of the preliminary findings.

Mature age students have been isolated as a special sub-grouping for in the opinions of the authors, these students are potentially very valuable graduates in a developing country. They posess a certain amount of work experience and more maturity than normal tertiary graduates, and would therefore be presumably that much further in the progression to handling positions of responsibility within the community. However they seem to be early casualties of the tertiary system; some dropping out with their quiet departure unnoted by teaching personnel until weeks after they have gone. They have also acquired a reputation for earning poor results if they do stay on. Why this situation prevails no one seems to know. In view of their potential usefulness the authors felt a special investigations was warranted.

Three aspects of this project will be reported on. The first is the preliminary attempts at gathering data on students from previous years to give perspective to the present study. The next will outline some early results of a survey on attitudes. Finally, a general description of the mature age students will be given.

Outline of study

The main study consists of four parts:

1. To sample student attitudes towards Mathematics in the Foundation Year.

2. To discover how their attitudes change during their first year.

3. To find and define any relationship between attitude and achievement.

4. To sample in particular, the attitudes and achievement of mature age students.

The attitude-measuring instrument will be discussed in a later section. The measurement of achievement will be scores on quarterly tests administered to mathematics students at Unitech during the year.

Subsidiary Studies

1. An investigation of Preliminary Year Students (grade 10 entry) beginning in 1981.

2. To investigate the progress of present continuing students in second year courses.

3. To look for differences in attitudes and/or achievement across:

   a) subject groupings

   b) PNGUT/UPNG

   c) male/female

   d) entry level groupings.

Definitions

After talking with colleagues it became clear that terms were needed to describe students in the study since no one seemed to agree on what exactly was a "mature-age student". Throughout this project the following terms will be used:

Continuing student - one whose entry qualification was completion of Grade 10 immediately prior to entry to University.

Repeating student - one who is repeating a mathematics course in which they have previously failed.

Year 12 student - one who completed Year 12 in the year prior to entry to University.

Mature-Age student - one who did not come to University directly from Grade 10 or Grade 12.

Background Data

One aspect of this project has led to attempting to gather the achievement results (pass rates) for the different types of students in the years 1978-1980 at UPNG and PNGUT. This was done to add a long term perspective to data collected this year. They began at PNGUT and immediately became enmeshed in the amazing record-keeping of the Student Affairs Office and the strange saga of the wandering computer.

It seems that in order to get the information required, the right question must be asked, a sound scientific principle. However, not knowing what was the right question, even after discussion with the records staff, the authors began by asking for a computer print-out of students registered in 1979 and 1980 listed by entry qualification. After a few weeks this was duly received, but it was a current list and thus did not show drop-outs or discontinued students. Only recently did the authors discover by accident the existence of a "history file" that may give the information required. This avenue of enquiry is being pursued. The computer on which the student records were filed has been sold to a commercial firm in Lae. The university's present computer cannot handle the same tapes. Therefore the firm was duly contracted to compile the student records for 1981. Access to this computer is thus rather limited. Table 1 gives the number of surviving students in 1981 in each of the categories. Now all that is needed is the original

numbers who enrolled during those years and a rough drop-out rate can be calculated.

Entry Qualification	1979 Entry	1980 Entry	Total
Overseas	22	32	54
PHSC (PNG High School Cert-Nat. High School)	102	185	287
Provincial High (grade 10)	129	166	295
University qual	9	25	34
Technical Schools	7	23	30

Table 1: Surviving students by entry qualification.

There are two problems with this list-one is to discover how many of them are mature-age students. Hopefully the history file will tell this. The other is to find out how a total of 55 students came to be classified PHSC (54% of this category), but who did not attend one of the secondary schools offering grade 12. The authors are still struggling with the background data and hope to have more concrete results in a later working paper, both as applies to Unitech and UPNG. This little struggle is noted to warn other researchers who may wish to investigate this area to tread warily and expect slow progress.

Attitudes to Mathematics

The method used so far to collect information on students attitudes to mathematics has been that of student self-report. The validity of such a method can always be questioned. An ever present threat to validity is the desire of students to present themselves in the best possible light; a common

and understandable reaction. As well, students may well interpret particular words or phrases differently to each other and to the authors. 'Often' probably means different things to different students. Although there are inherent difficulties with this method of collecting data, the information provided on students' perceptions of mathematics and themselves as learners of this discipline is still useful in its own right, and is a useful starting point for the construction of structured clinical investigations which the authors hope to conduct at a later date. In reporting such data the authors also hope that lecturers will become aware of possible variations between their expectations of students' perceptions and the way in which students actually do view mathematics and themselves as learners. Perhaps this very awareness may well lead to better interaction within the lecture theatre.

Two survey instruments have so far been used to collect some data on the students' attitudes to mathematics. The subjects were foundation year students. The first is a general Likert scale, 'Attitude to Mathematics', consisting of ten positive statements and ten negative statements concerning mathematics with five response columns. Table 2 gives some examples of the statements.

3.	Mathematics is very interesting to me, and I enjoy maths subjects.
6.	I am unable to think clearly when working on maths.
10.	Mathematics makes me feel as though I'm lost in a jungle of numbers and can't find my way out.

Table 2: Examples of the statements from the 'Attitudes to Mathematics' instrument.

Table 3 shows the percentage responses on this instrument by groups and the mature age students separately. A low figure indicates a liking for mathematics.

GROUP	N	$\bar{X}$	S.D.
A.B.S.	61	40	13.8
Engineering	71	36	9.2
Chemical Technology	29	43	8.9
Architecture	18	36	9.5
Surveying	15	37	8.4
Forestry	12	40	10.7
Mature age students	10	43	

Table 3: Percentage responses to the 'Attitude to Mathematics' instrument.

No tests for significant differences have been carried out on this data, but it is doubtful whether any educationally significant differences exist. Perhaps for the general student population mathematics lecturers may have hoped for a more positive attitude, since the students do attend a technological university where for most courses mathematics is fundamental. The more interesting result will be to see whether their attitudes change during the year.

Only ten of a possible fifteen mature age students' responses were identified in the collection of response sheets. Wastage could be due to non attendance at the class when the data was collected, and the changing of their names from that originally given to the authors; an ever present problem for researchers in Papua New Guinea. Asking the mature age students who had not responded to complete the instruments at another time was considered but rejected. The authors

believed such a variation in the conditions under which the instruments would be completed would probably significantly influence their responses. It can be seen from Table 3 that the mean for the mature age students is equal to the group who most dislike mathematics. It seems worthwhile to probe this area in later interview situations.

The second instrument, 'Attitudes to Doing Mathematics', was developed for this project. Originally 24 statements were submitted to 70 second year students. The results were factor analysed and four factors isolated which accounted for twelve of the statements. Ten of these statements plus four isolated statements comprised the final instrument. (The four isolated statements will not be dealt with in this paper). Again factor analysis was used on the responses of the 206 first year students. Only one of the ten statements dropped out. Table 4 gives the results of these nine statements for all the students combined, with mature age students' responses given in brackets. The results from different subject groups is not shown, since there seemed to be little difference between them. A low mean score indicates agreement with the statement.

The statements have been grouped in the clusters which the factor analysis produced. Headings which may give some guide to the underlining trait have been added.

The first three factors seem to the authors to give some insight into the manner in which these students approach their study of mathematics. By taking the 'Understanding' factor in isolation, it could be hypothesized that these students indeed have outgrown school mathematics, and are at last looking for the underlying conceptual framework of the mathematics they are studying. However the other two factors need to also be considered. These perhaps may bring disappointment to the mathematician.

	$\bar{X}$	S.D.
UNDERSTANDING		
1. Being able to tell someone why an answer is right is important.	1.51 (1.50)	0.78
2. Knowing how to do a problem is as important as getting the right answer.	1.39 (1.30)	0.74
3. Being able to tell someone how to do a maths problem is important.	1.89 (2.20)	0.87
RULE DEPENDENCE		
4. There is always a rule to follow in solving math problems.	1.63 (1.80)	0.87
5. Doing maths means you have to have lots of practice at following rules.	1.94 (2.20)	0.96
RULE IMPORTANCE		
6. Making guesses is a good way to work out maths problems.	4.20 (4.30)	1.05
7. It does not matter if you do not know why a maths rule works.	4.28 (4.80)	1.01
CONFIDENCE IN ANSWERS		
8. If I get the right answer for a question, I think that I'm lucky.	3.33 (4.10)	1.26
9. I always have to ask the teacher if my answer is correct.	2.98 (3.80)	1.67

It would seem that for students, the 'why' and 'how' of mathematics is interpreted in terms of rules if the 'Rule Dependence' factor is any guide. Thus 'explaining' the workings of a problem would be a matter of relating the rule. This is reminiscent of a comment by Ginsberg (1979) when referring to some secondary students who had been allowed to work in groups. He commented that the brighter students helped weaker students by 'explaining' how to do a problem by simply showing how to set out the numbers on the page.

The third factor is a little more difficult to interpret. The second statement is a double negative which, with many students not being fluent English linguists, may have caused difficulty with its interpretation. In future research this statement will need to be reworded. However, taking this at face value for the present, it would seem that students are again expressing the belief that being able to apply rules is vital to mathematics.

In examining the responses of the mature age students, they do not seem to be much different to the average student.

Overall then it appears that these tertiary students see themselves as rule bound as far as mathematics is concerned. This will be an interesting area to probe in clinical studies later. Another strand to investigate is the comparison of these students with those taking mathematics as a major at UPNG. It may well be that these students are simply reflecting the 'surface' nature of this technological institution where mathematics is viewed as a pure service subject.

The fourth factor isolated seems to relate to the confidence students have in the correctness of their answers. This intriguing area was bought to the attention of one of the authors in an earlier study with year 10 students in Australia (1980), and in some work by R. Seldon, a colleague of the authors (Seldon, 1980). The earlier studies seem to indicate that weaker secondary school students tend to have little confidence in their answers, and will change them practically at random. In the present study it is disturbing to see teritiary students being uncertain in this area. Interestingly, the mature age students appear to have significantly more confidence in their answers. An immediate follow up exercise will be to find out whether the confidence of the mature age students is misplaced.

Mature Age Students' Profile

Mature age students were identified through the help of mathematics lecturers. They were asked to return to the authors the names of any mature age students and nineteen have been identified in this way. Six each are enrolled in A.B.S. and Surveying, four in Engineering, two in Forestry and one in Chemical Technology. Three in Surveying and one in Engineering are in other than the foundation year.

Of the possible nineteen students, interviews with fourteen were held in the first five weeks of term. Although letters were sent personally via lecturers to the other five, they did not respond to the invitation to talk. Since the authors were wanting initial reactions from the students to their new way of life, attempts to interview the remaining five were not pursued. Some data on two of these five students was gained from a general sheet attached to the survey forms discussed earlier.

Although there is clearly much more variation in the age range of continuing or year 12 students embarking on tertiary studies in PNG than in western countries, their average age would still be 19 years. The median average age for mature age students at PNGUT this year is 25 with a range of 20 to 45. Of the 16 students for which data was collected, all are sponsored; 8 by the government, 5 by private employers, 1 by PNGUT and the two Tongan students by the Australia Government.

Since the courses at PNGUT are written to follow on from the syllabi followed in Provincial or National High Schools, it is useful to note how long it is since these students attended school. The range of intervening years is 1 to 26 with the median average being 9 years. Clearly in that time courses in schools have changed and the mathematics courses at PNGUT have also changed, partly in response to this.

Thus there is no guarantee that the mature age students have covered all the prerequisite school material for the university courses. The break down in schools attended by the mature age students is 8 from Provincial High Schools, 4 from National High Schools, 2 from Technical Schools (year 10) and 2 from Grammar Schools in New Zealand.

From the results of the students in their exit year from school, they were not high fliers academically, a rather expected result. Upper passes predominated. Since leaving school 80% of the mature age students have completed successfully an extra certificate or diploma course. Thus some hope for their academic ability could be held. All the students had completed at least one full year of work.

In probing the reasons why the mature age students returned to full time study, in some cases after many years of working full time, it became clear that they were not seeking a new direction in employment. In only two cases had students drastically changed their type of employment since leaving school; one from patrol officer to accountant and the other from banking to aircraft maintenance. Both changes were made at least four years before enrolling at university. In all cases then, the enrollment was seen by the students as an upgrading of qualifications to enable them to more effectively carry out their work duties, and to assume a more responsible position within the government department or company which employed them. This is in marked contrast to the normal reasons for enrollment of mature age students in western countries. There, personal self fulfillment, change to a better job or more money are the common reasons. (Willaims, 1979; Hore and West, 1981; Parry, 1981).

These students were also questioned as regards their confidence in passing their degree. All showed confidence; some being very confident and only two being a little wary. They clearly felt their work experience would help in the practical aspects of their courses, but only two believed this would help their theoretical understanding. There was a general worry about

not being able to remember school work. Any mathematics completed in a certificate course did not seem to help. As one student commented, "We only played around with maths at the Tech." Whether of course this is a real problem will need to be investigated. Perhaps if these students are to be helped, starting explanations from a practical, real life perspective may be best.

There was a mixed reaction to other reasons proffered as to why they should cope better than other students. Only a few were willing to suggest added maturity would help, or their own personal drive would see them through. Six of these fourteen students expressed the opinion that since a sponsor was supporting them, they just had to pass: They could not 'let the sponsor down'. This was rather an unusual reason to the ears of the authors, both expatriates. They could not recall such reasons being given in their own countries of Australia and the United States.

However, apart from the nagging worry of not being able to remember school work, there were other social problems which lessened the students' confidence. These seemed to predominate with the eight married students.

Quite clearly the six who were on campus away from wife and family were feeling lonely and had problems with the 'younger' students general behaviour. The majority of these as well as three of the older single students found the dormitories very noisy. It may well turn out that these social problems are as much cause for the mature age students failure as academic problems.

If the amount of time spent in study was directly related to achievement, there is no doubt that mature age students would do well. All these students spent the spare time during the day studying, at least three hours each night, and at least four hours over the weekend. Most spend much more time than this studying. For example one student, apart from the time through the day, studied till after midnight in his room each night, completed about three hours on Saturdays,

with four hours on Sunday preparing for the coming week. It is reasonable to suspect that this amount of time is more than the average student spends in study.

The quality of the study however seems to be lacking. Only two students used the library as a resource; the others saw it only as a place to study, with one student using it only to borrow fiction from. To 'study' simply meant to complete given exercises or sets of problems, especially in mathematics. Perhaps this reinforced the attitude to doing mathematics by rule as noted earlier. Fortunately none of these students felt inhibited in approaching lecturers for help.

Interestingly when questioned specifically about their confidence in handling mathematics, there was a clear fifty-fifty split when asked whether they were good at mathematics in school. All expressed a liking for the self paced unit system used in the mathematics department. Only three students indicated that they were having difficulties with mathematics and felt they were not coping.

Two put it down to the length of time since they last attended schools and the fact that they had forgotten so much. The other found it difficult to read the units.

The general picture gained so far of mature age students is that they have been absent from studies for the most part for a long period of time and most left after year 10. They are however willing to work long hours, have confidence that they will succeed in their studies, and believe they are coping with the mathematics so far. There is some question as to the quality of their study habits and there seems to be a certain amount of social unease among the group. However this alone does not explain the high failure rate of past years. The authors suspect that much of the confidence of these students is misplaced. They have not formed a true appreciation of the breadth and depth of study expected, nor will they come to grips with such by simply attempting to

complete in a mechanical fashion all problems that are set. Maybe more interaction on a one-to-one level with lecturers is needed to break this nexus very early in the year. This conjecture is based on very early data and it may well alter as the project progresses in following the changing patterns in attitude of these students.

REFERENCES

AITKENS, L.R. 'Attitudes Towards Mathematics'. Review of Educational Research 40(4): 551-596, 1970.

CLARKSON, P.C. 'The Newman Error Analysis - some Extensions'. in Research in Mathematics Education in Australia, 1980 Vol 1, ed. by B.A. Foster, Hobart, Mathematics Education Research Group of Australasia, 1980, pp 11-22

GEESLIN, W.E. 'Using Writing About Mathematics as a Teaching Technique.' Arithmetic Teacher 70 (2): 112-6, 1977

HORE, T. and WEST, L. (eds) Mature Age Students in Australia Higher Education Higher Education Advisory and Research Unit, Monash University, Clayton, 1980.

PARRY, D. 'Student Development in Higher Education: A Consideration of some of the Inter-Relationships Involved', Unpublished paper, Papua New Guinea University of Technology, 1981.

SELDON, R. 'Conceptualizing, Understanding and Performing Mathematical Procesures' in Research in Mathematics Education in Australia, 1980. Vol 2, ed. by K. Milton, Hobart, Mathematics Education Research Group of Australasia, 1980, pp. 161-172.

WILLIAMS, J. Education, Training and Employment: Report of the Committee of Inquiry into Education and Training. Australian Government Publishing Services, Canberra, 1979.

RESEARCH ON THE TEACHING OF PROBLEM SOLVING AT THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY: RETROSPECT AND PROSPECT.

Lilia S. Dube
Mathematics Department
University of Technology

A most challenging task of the mathematics educator is to teach the capability to think out independently the solution to a real problem. In the latter part of 1976 the writer started a series of studies into the teaching and learning of problem solving in the mathematics classroom. These studies were largely exploratory and preliminary and focused on five basic themes, namely:

1. The meaning of a problem
2. The 'clinical' method of research
3. Problem solving protocols
4. Teaching an algorithm for problem solving
5. Group problem solving

The lessons learned and the propositions generated for future research are discussed in this paper.

1. The Meaning of a Problem

A square whose side is s is inscribed in the triangle with attitude a and base b. Explain why $s = \frac{ab}{a+b}$

A student of mathematics to whom this question is posed for the first time will not have a ready explanation. He is "faced with a solution seeking situation to which automatism does not provide an effective answer"[1] Situations like these are the problems, the teaching and learning of which make up the substance of the researches discussed in this paper.

Retrospect: This characterization of a problem (as distinct from an exercise which may be solved by recall) has proved useful in the conduct of two completed researches.

The first, an exploratory one, used this concept of a problem to determine the real problems of a random sample of elementary school children in 1976 and to motivate them toward the solution. The analysis of the audiotapes of the verbalizations of their problem solving processes resulted in the identification of distinct ways in which the sample solved their problems. These ways were termed problem solving protocols.[1]

In a second study, on experimental one, this concept of a problem was used to motivate 4 groups of Cartography students at the University of Technology in 1980 [2], to solve problems in geometry. In this study it was determined that problem solving ability in geometry could be developed when:

(a) an algorithm for problem solving is taught,

(b) students solve problems in groups

Prospect: In both these studies the subject's (or group's) awareness of the nature of a problem led him (or them) to the solution. Could making the mathematics student aware of what a problem is (and what problem solving processes are) make him a more efficient problem solver? A teaching experiment using explicit lessons on the nature of a problem as the treatment would lead to what every mathematics teacher is looking for - a method for teaching problem solving.

2. An Alternative Method of Research - The Clinical Method

Problem solving is essentially a human activity. Hence, the controlled statistical studies which have been useful in other disciplines where the objects studied were non persons (seeds in agriculture, light waves in physics,.....) cannot obtain the same validity and reliability when used in research on the teaching and learning of problem solving. To study human problem solving it is important that the problem solver be considered as an individual. This is possible only when the researcher gets intimately involved with thought processes, verbalizations, etc.. of the subjects under observation. Such involvement can be found in the clinical method of research.

Retrospect: Both the studies took the form of the clinical investigation as described by Romberg and Uprichard in their position paper "The Nature of the Clinical Investigation". In these paper the authors cite two aspects of this method of scientific inquiry. The first aspect consists of analytical/ synthetic procedures which lead to guiding models and paradigms (the 1976 study) and to researchable propositions (the 1980 study).

Prospect: Both studies however have not considered the second aspect - methodological techniques which focus on the methods used. The planning and conduct of current and further researches are now including a critical analysis of the method itself.

3. Problem Solving Protocols

The term "protocols" connotes "usuality" or "fixity". In the 1976 study the sample of school children solved their problems outside the classroom setting. Hence it was hypothesized that they were using their own unique, customary ways of solution. This is the reason why these ways were called their problem solving protocols.

Retrospect: That the set of problem solving protocols of children learning basic arithmetic was not empty was determined by the 1976 study. Despite its limitation of short taping time and the small sample, the research was able

to identify two categories of protocols, namely direct and inverse approach protocols. Both approaches were carried out through the use of a definition, through the building of models, and through searching a store of recalled number facts.

Prospect: But where did these protocols come from? Were they explicitly taught in the classroom, were they learned as a product of classroom teaching, or where they learned somewhere else?

Herbert Ginsburg [3] of the former Childrens' Mathematics Project hypothesizes that:

> ....children develop a powerful informal mathematics, especially a practical arithmetic outside the educational context."

Were these problem solving protocols (especially those which use concrete representations like counting, tallying, etc.) learned informally? Information on this informal mathematics (if it exists) could provide a natural starting point for formal instruction in mathematics.

4. Teaching an Algorithm for Problem Solving

In mathematics an algorithm is a sequence of prescriptions which when used will attain a desired result. In How to Solve it G. Polya set forth a series of prescriptions towards the solution of a problem, namely.

1. Understand the problem
2. Make a plan
3. Carry out the plan
4. Look back

This series of prescriptions can be thought of as comprising an algorithm which when followed will solve a problem.

A venture is a segment of teacher - student(s) discourse dealing with a single topic and having a single content objective. Within a venture subsets of utterances (called moves) may be classified according to their function in attaining the objective of the venture. A sequence of moves is a strategy. The following moves in the teaching of an algorithm have been identified [4].

1. Preparation move
2. Assertion move
3. Denomination move
4. Interpretation move

5. Justification move

6. Application move

A strategy where the assertion move is the first or the second (where the first is a preparation move) is an expository strategy. Heuristic strategies are those where the assertion move is either the ultimate or perultimate move in the sequence.

Retrospect: By using an expository strategy, the 1980 study established that the Polya algorithm can be taught and learned just as any other mathematical algorithm is taught and learned.

Prospect: But the Polya algorithm was taught to and learned by students in only one field of study (Cartography) and was applied only to selected few geometric problems. Will the same results be attained if the study was done on students in other disciplines solving problems in other areas of mathematics?

5. Group Problem Solving

The student of mathematics (or of any other subject) comes into the classroom with a personability shaped by the socio - cultural environment in which he was born and reared. In Papua New Guinea today, it is still the villages, the collection of hamlets, or collection of homesteads, that is, as far as indigenous custom is concerned, the largest effective legal unit. In the villages, such matters as marriage arrangements, ceremonial activities, type of work, etc., are debated and decided in a village meeting or public forum where every member of the village attends. In the 1980 study 20 second and third year students of mathematics for cartography solved problems in group sessions which similated the free discussion of a village forum.

Retrospect: The group sessions established that students can be motivated to solve their problems and to approach the solution with confidence and enthusiasm. This led to a near - perfect success rate in the group problem sessions. This high rate of success was also evident in the final examination of the course which consisted of questions which required the examinees to do real problem solving.

Prospect: The realization that problem solving is teachable and learnable was the outcome of the 1980 study. The discovery that the teaching and learning of problem solving is a slow and continuing process was an incidental but a more significant outcome.

LOOKING AHEAD

Thus, these two studies (together with other bits of uncompleted researches) have generated the proposition:

> The task of producing real problem solvers formally begins from the moment the child enters his first mathematics classroom and should consider not only the informal mathematics he has acquired earlier but also the culture in which he was reared.

A proposition in mathematics (or in any other body of organized knowledge) is a statement to be confirmed or denied. This year (1981) the directions which the research on problem solving at the University of Technology have taken to confirm or deny this proposition are:

1. Further in - depth studies over a longer period of time to analyze the characteristics of small groups (and also of individuals) carrying out problem solving.(i)

2. Researchs into the training of prospective teachers of primary school mathematics engaged in real problem solving.(ii)

NOTES

(i) The ways in which 40 students enrolled in second year mathematics for surveyors (14 direct entries and 26 continuing) solve problems in geometry, working in groups of 4 and 5 are being observed and recorded; and their verbalizations are being audiotaped.

(ii) This study is now in progress in collaboration with Goroka Teachers' College.

REFERENCES

1. Dube, Lilia S. "The Problem Solving Protocols of Papua New Guinea Children". In Southeast Asian Bulletin of Mathematics. Vol 1, No. 2, November, 1977. pp. 50 - 56.

2. Dube, Lilia S. "Moves and Strategies in a Problem Solving Venture - A Study of the Teaching of Problem Solving in the Papua New Guinea Setting." Paper presented at the Second International Conference or Mathematical Education for Southeast Asia. Kuala Lumpur, April 20 - 24, 1981.

3. Ginsburg, Herbert. "The Children's Mathematics Project: An Overview of the Cornell Component". The Journal of Children's Mathematical Behaviour Summer, 1976. Supplement Number 1, pp. 7 - 31.

4. Polya, G. *How to Solve It. A New Aspect of Mathematical Method.* Princeton, New Jersey: Princeton University Press, 1957.

5. Semilla, Lilia V. "Moves and Strategies in a Principle Venture". Unpublished Doctoral Dissertation, University of Illinois at Champaign - Urbana, U.S.A., 1971.

ADULT NUMERACY WITH A CALCULATOR: SOME PROBLEMS

ALLEN EDWARDS

DEPARTMENT OF COMMERCE NUMERACY PROJECT

1. Vastly less attention has been given world-wide to Adult Numeracy than to the corresponding problem of Adult Literacy. This may be understandable when one contemplates what numeracy must include if it is to be any practical use to a villager.

   1.1. The current usage of number skills in Papua New Guinea villages today seem generally limited to counting, together with buying and selling in units of 10 toea or a kina.

   1.2. Potential uses which have been identified so far include:-

   for trade stores: buying and selling in 1 toea units, checking invoices, pricing goods, keeping accounts, stocktaking and leakage checks.

   for selling produce: weighing (in kg), finding value given price per kg.

   for business projects: counting money, pricing products, keeping accounts.

   for construction: Measuring, totalling lengths, costing, finding the number of sheets of iron, ply wood etc required.

   1.3. To enable a villager to carry out these operations without a calculator he or she would need to be taught the following skills:

   Addition and subtraction to K1000.00. Short

and long division (by 24, 48 etc for trade stores, by 76, 1.22 and 2.44 for construction).

Percentage (mark ups of 10%, 12½%, 25% etc)
Proportion (Business Project pricing).

1.4. By contrast, given a calculator, the only skills needed are to understand how and when to use +, −, x, ÷, ce, c, % and the memory, and to realise the need for checking results.

Some further skills which can be taught at the same time with the help of the calculator are:

Learning number bonds up to 9 + 9.
Finding change from K1.00 mentally.
Measuring (m and cm).
Weighing (kg)
Clock and calendar (including "counting on").

1.5. A package containing these skills together with an emphasis on how to teach them to others can be taught to villagers with Grade 6 in a 4-day course. Research is currently being carried out to discover whether this or some other organizational pattern will enable these same skills to be passed on by these students to unschooled adults in their own villages.

1.6. By contrast the task of teaching the skills required if no calculator is available (including facility in long division) would seem to be a virtually impossible task. Indeed, any attempt to slant the teaching in Primary schools so as to include facility in such skills would seriously warp the mathematics curriculum. The simple way to convert the present Primary school course into one that would be of practical use in the village, would be to include a month's concentrated course on the use of the calculator for those students in Grade 6 who will <u>not</u> be proceed-

ing to secondary education.

This development is much to be desired, not only would it make an immense contribution to rural numeracy, but it would also provide the Grade 6 leavers with a genuine achievement that would appreciably compensate for the sense of failure with which many such "drop-outs" must currently return to their homes.

2. The rest of this paper will be devoted to the study of a number of problems and their chosen solutions which have arisen in the course of the present experimental work in this field.

2.1. The first major problem was met while courses were being written for businessmen in PNG, before adult numeracy was seriously considered. This was the question whether or not the decimal point should be used in calculations with money. In the absence of a sound appreciation of decimals, which would have enabled the users to choose for themselves, a clear decision was needed.

In my earliest programmes I chose to use the decimal point, including long explanations of what should be written when the answer to K1.30 + K1.20 turned out to be 2.5: the obvious temptation was to write 25t or K25. Teaching the insertion of a zero, or perhaps two zeros in special cases proved to be a substantial problem. On the other hand omitting the point would give results such as 513279 for K5132.79.

In the event I chose to omit the point, but in doing so I was influenced by an outside factor. At the time I was also concerned with the training of shop assistants in a big store who used sophisticated electric tills. These I discovered had an 'arithmetic' function which automatically inserted the point in the answer: the user did

not have to learn to insert it. So, I decided, neither would we.

Later experience confirmed the decision. As soon as division is used one meets a string of numbers with a point in some where among them. The easy way to handle this was to say "forget anything after the point". This could only be done if the working was in toea.

2.2. As a mathematician I was worried about the propriety of subtracting a large number from a small number without giving any teaching on the subject of negative numbers. When totalling a bill and calculating change however the total is already on the calculator and the change can be found at once by subtracting the cash offered.

Bearing in mind that an explanation could always be given to anyone with a knowledge of negative numbers. I simply told the students to ignore the - sign after the answer.

In general one can use the minus sign for "differencing" and any concern as to whether the answer be positive or negative can be assuaged by using the +/- key to remove an unwanted minus. The need to do this however has so far only occurred once in my work:

Some sophisticated users found an error of a certain magnitude in one of a set of numbers which were already totalled. The total was then corrected by adding or subtracting the amount of the error.

2.3. Another problem which worried me greatly at first with my educational rather than commercial background, was whether one should round up or down or to the nearest. Having spent many hours of my life trying to explain to students how to round

to the nearest, I did not relish the prospect of doing so with PNG businessmen, yet to allow an ambiguity in the answer was pedagogically unacceptable. I found a variety of practices in commerce, the most general seeming to be "If you are charging someone round up, if you're giving something away round down". This worked with calculating discounts, but I was more concerned with markups, which are the subject of controlled price legislation. Here the law states that rounding up is only permitted in the final stage of the calculation.

Clearly there was no universal solution to this problem, the one I adopted was 'always round down except when there is a good reason to round up'. We came across examples of the latter in the case of calculating the number of sheets of corrugated iron needed for a roof of given length. The prospect of rain falling through the uncovered gap quickly convinced students of the need to round up. In this case "rounding to the nearest" would not keep you dry either.

With Unit Cost Price I decided to round down, but I ensured that calculation of the selling price normally used the correct figure by doing the whole calculation as one process, leaving rounding to the end. The only occasion when this was not possible was in the calculation of the percentage mark-up given the selling price. In this case you have to calculate the Unit Cost Price first: putting it into the memory would be cumbersome. Using the rounded down value of the UCP gives a biased result but when the major problem is understanding of the principle, it is a small matter to have an error of this sort of magnitude in the working.

2.4. My most serious problem was to decide what units of measurement to use. Clearly the idea of using a variety of units was to be avoided if at all possible.

Centimetres are used in school, but millimetres and metres are the official SI units and are used in the professional training of carpenters. The sort of problems I had in mind involved lengths of buildings and the construction of furniture with sawn timber. The use of millimetres was ruled out at once and even centimetres involved numbers around 1000 which would cause problems for villagers.

To my delight it occurred to me that I might use metres and centimetres in the same way that we use kina and toea. The result was that the numbers involved were of the same sort of magnitude as those in the rest of the programme and the techniques for dealing with them could be transferred direct from those used for money.

This decision, to work in metres to 2 decimal places, or in centimetres for lengths under a metre, had some drawbacks: accuracy was limited to the centimetre and special measuring sticks might have to be provided. I decided however that villagers were unlikely to be worried by an inaccuracy of the order of a centimetre and I proceeded to design my own measuring stick. This was subsequently produced for me by the Department of Education Materials Unit at Idubada and I am most grateful for their co-operation. My metre stick differs in two ways from that produced by the same people for use in schools. First, every centimetre is labelled whereas in the schools version they are only labelled every 5 cm, involving interpolation. Secondly in the design for adults I used the labels .01 .02 ..... .99 to ease the transition to writing the result in metres.

2.5. I have time to mention only one further problem, for which we discovered an interesting solution. We found that all villagers, and most government officers too, found it exceedingly difficult to "count on" when trying to determine the time 2 or 3 hours later,

or the expected date of birth of a pig for example, for which the gestation period is reckoned as 3 months, 3 weeks and 3 days. The story of the Resurrection has always worried me slightly, not for the more usual reasons but because of its insistence that Christ rose on 'the third day'. By no stretch of my imagination could I believe that Sunday was the third day after Friday. I now know that difficulty derived only from the peculiar habit that technological societies have of starting to "count on" from the member of a sequence following that from which one starts.

This has the advantage of course that 'counting on' then corresponds to the sophisticated concepts of addition and subtraction. But no such concepts motivate the Papua New Guinean, or even I now realise, the Jews of the time of our Lord.

If you are born in 1979 you are 2 in 1980 aren't you? - count on: 1979, 1980. If your birthday was in March you are 2 months old in April. I have not yet investigated how soon after the actual hour of birth a Papua New Guinean child acquires the age of 1 day, 1 week, 1 month or 1 year. It might be a suitable study for a thesis on language and mathematics.

Unfortunately, in dealing with the expected birthday of a pig I was not free to accept this otherwise delightful convention, so we had to find some way of convincing our villagers (and officers of the Department of Primary Industry) that in counting on, you do not start with the day, week, month or year where you now are. It occurred to me that games of the Ludo variety all involved this same concept and that I in my Western home had learnt the principal very early on from my realisation that if I threw a 1 on the die I really could move on one square.

So how could we introduce such games to the Villagers? Fortunately I had when at the Mathematics Education Centre arranged to print 'boards' (as recommended in the official school syllabus) on which a Car Race was

represented by squares numbered from 1 - 100. Supplies, thanks to the generosity of my successor, were readily to hand but we had not yet attempted to use them because we had no dice. Any standard size dice supplied to a village would assuredly have a very brief life and the Idubada Materials Unit would not be making any more 5 cm cubes for some time.

But of course, the calculator came to our rescue again. Programming it to produce genuinely random numbers would not be possible, but all that was required was a procedure that would give unpredictable numbers preferably from 1 to 9 so that the teaching of number bonds would not be restricted to 1 - 6.

The Bible again provided the rest of the answer: 7 is an excellent number, not merely for the days of the week but because successive divisions of <u>any</u> number by 7 on the calculator will result in a sufficiently unpredictable final digit. To convert calculators into dice one merely has to say "put in any number you like, press + 7 = and then continue pressing = and reading off the last digit until you are left with zero, then start again".

This worked admirably with a group of DPI officers in the Southern Highlands. They thoroughly enjoyed the 'Car Race' game. Subsequently when one of them tried to find the expected date of birth of a pig by starting to count from the day, the week and the month of conception, we were able to point out exactly why he had been playing the Car Race game. I have rarely observed such an effective and well appreciated example of transfer of knowledge.

REFERENCES

EDWARDS, A. *Arithmetical Skills of Adults in Papua New Guinea: A Subjective Enquiry*, September 1980.

DICKIE, M. and EDWARDS, A. *Newsletter No. 1 of the Department of Commerce Numeracy Project, January 1981.*

EDWARDS, A. *List of Units Available For Adult Numeracy Courses and Programme For A Typical Course, As Revised 1st April 1981.*

A Test of Measurement - Or is it ?

Harold R. Frederick
Goroka Teachers' College

My aim during this session is to stimulate discussion of the possible reasons for the high failure rate among our post-grade 10 students at Goroka Teachers' College on mastery tests of Measurement. I am exploring the possibilities and have yet to complete the explorations.

You were given 3 tests of measurement that were used in our Arithmetic Skills course last year. Other topics in the course are Whole Numbers, Fractions, Decimals, and Percent. We try to make the level of the problems at that of grade 8/9 of the Papua New Guinea high school. All students are required to pass the course in one year or be terminated from the College. They must pass at the 85% to 90% level (mastery). The table below shows the failure rate after 3 attempts at tests on each topic.

TOPIC	% FAILING
Whole Number	1%
Fraction	4%
Decimal	2%
Percent	7%
Measurement	23%

The number of students was 91.

The students attempt a pre-test before instruction on a topic begins, does a post-test after two weeks of instruction, and a final test after one more week of instruction, if needed. A pass on any of these tests exempts the student from further instruction and tests.

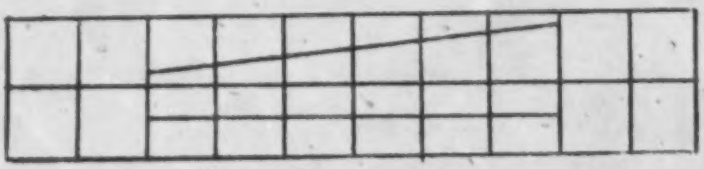
A similar course with 29 older students (community school teachers) had similar results: 3% , 3% , 7% , 11% , and 21% in the same order as the table above. I have not looked closely at the students of this latter course.

The high percent of failing students was a bit of a shock to me when first seen. It was not so shocking to veteran members of the Mathematics Department of Goroka Teachers' College.

The outcome of the investigations will hopefully help us to build a better course on the measurement topic of our skills course. We have failed to "get through" to 23% of our Prelim. Year students on the topic of Measurement.

My first thoughts were that the students were not making sense of the problems they were to solve on the tests. I constructed the Cloze type test that I have given to you and administered this to the failing students. The errors were minor and showed not difficulty in writing meaningful sentences when blanks were to be replaced with words.

I next interviewed 8 of the failing students for 2 - 3 hours to gather information about their knowledge of concepts of length, perimeter, and area and the measurement of these. Time was not investigated but will be looked at on a later date. Two errors on length showed up and were easily corrected. In answer to the following question two students said the lines were of the same length because they went the same number of squares. When asked if they were to measure them which would be longest they gave the correct answer.



A is longest _____

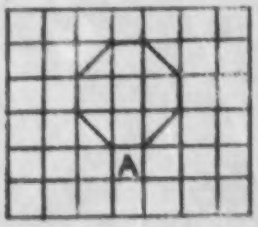
B is longest _____

A and B are the same length _____

Another interesting error was on this question:

The distance around the edge of A is:

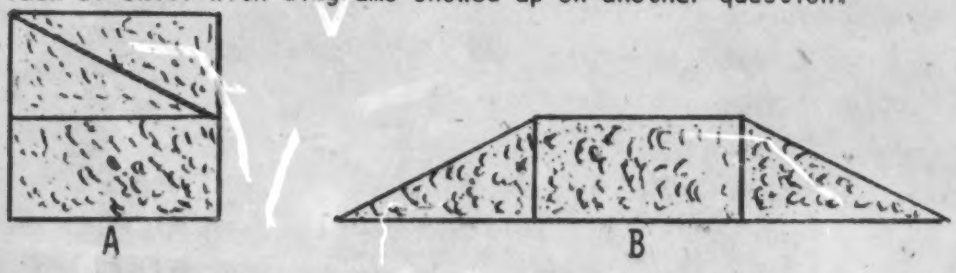
8 cm more than 8 cm less than 8 cm you can't tell



The answer in error was "less than 8 cm". Why do you think this response was made? What was the student responding to?

It appears that some errors will come from mis-understanding of the question or of the diagram and not from lack of knowledge of the concept or of the measurement skill required. We need to be careful in our use of diagrams both in instruction and on tests. We need to look at the number of errors that may be of this type on our Measurement tests.

The lack of skill with diagrams showed up on another question.



A has the longer perimeter.

B has the longer perimeter.

A and B have equal perimeters.

The answer in error was " A and B have equal perimeters"

I wanted to look further at the relation between English proficiency and Measurement test results. I looked at the correlation between the Michigan Test of English Language Proficiency (given to all Prelim. Year students) scores and the Measurement test score, and the first test score total of the other 4 topic tests of the Skills course. The table of results is below.

Michigan test with score of first Measurement test	$r = .28$ $P < .01$
Mich. test with total of pre-test scores of other 4 topics of the Skills course.	$r = .23$ $P < .05$
Total of the 4 pre-tests with the Measurement test	$r = .31$ $P < .01$

A scatter diagram did not disclose any other relationship besides this weak linear one. The relationship is not as strong as I would have expected. Another investigation at the College is showing that with our students other factors beside language proficiency determine success in the Mathematics course work.

The differences between students who score 80 or above on the Michigan test and those who score less than 70 are being looked at but the significance of the differences have not been calculated. The tables below give information on students when grouped in this manner.

Michigan $\geq$ 80 (n = 22)	Michigan $<$ 70 (n = 25)
No. passing on	No. passing on
pre-test: 5 / post-test: 12 / final: 2 / fail: 3	pre-test: 1 / post-test: 14 / final: 3 / fail: 7
Average of Measurement test scores for this group: 9.45	Average of Measurement test scores for this group: 7.40
Average of the total pre-test scores of the other 4 Skills course topics: 74.48	Average of the total pre-test scores of the other 4 Skills course topics: 64.12

My exploration of the factors involved in student failures on the Arithmetic Skills Measurement tests is in the early stages. The few outcomes so far can help us to provide better instruction and to write better tests. I will want to look closely at the way failing and successful students think about measurement test items and the strategies they use to solve the test items.

As this investigation has many more kilometres to run, I solicit your ideas on the factors of failure on these tests and on improved methods of instruction.

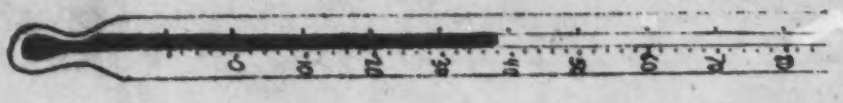
FILL IN THE BLANKS TO MAKE SENSE

NAME _____

NUMBER _____

Some words are missing from these sentences. Put words in the blanks that will make a sentence that sounds right and makes sense.

1) Measure this _____ to the nearest centi_____.

2) Read the _____ on this _____ to the _____ ^{o}C. 

3) Which of these _____ is closest to that of a 4 W.D. Suzuki hardtop like Monica's or Mike's?

8000g 50kg 10 tonnes 1000kg

4) Which of the following _____ would be _____ to last night's _____ in Goroka?

120^{o} C 10^{o} C 40^{o} C -10^{o} C

5) Laki _____ driving to Mt. Hagen at 10.45 am. He arrives in Mt. Hagen 4 hrs 25 min. _____. At what _____ does Laki _____ in Mt. Hagen?

6) Six months ago a student _____ 73.5 _____. He has been very sick and lost 7.8 _____ in weight. How much does he _____ now?

7) A bottle of Laga Cola _____ 375 _____ of drink. What is the _____ of 7 bottles.

8) The school day _____ at 7.50 am. In the _____ there are 4 periods of 40 _____ each, then a 15 minute break, one _____ for work parade, and 1 hour 15 min. for lunch. At what _____ do _____ start _____ lunch.

9) How _____ 350 cm lengths of material can you cut _____ 12 _____?

10) Write 5590 seconds as _____, minutes and seconds.

11) Arna buys 4 - 75 _____ tins of coffee , and
5 - 250 _____ tins of coffee.
How many kg of _____ does he _____ altogether? Answer with 2 _____ places.

12) A student _____ various _____ of wool. They are 67cm, 185mm, 2.6m and 105 _____. What _____ of wool does the _____ _____ altogether? Answer in _____.

13) 2.3 _____ of wood costs K8.00. How _____ does one meter of _____ cost?

Solving word problems in a second language and reading proficiency

by

Peter L. Jones

Abstract An information processing model of reading is used to provide a framework for discussing the response patterns to a language and mathematics test recently administered in Papua New Guinea. It is suggested that limited proficiency in reading, in terms of the number of 'words' that can be processed in a single fixation, can restrict a child's ability to determine the mathematical relationships that underlie certain types of word problems, and that it is in this area that second language learners are at a particular disadvantage.

INTRODUCTION

In a recent study of language and mathematics (Jones 1981a, 1981b) some 678 children in PNG community and provincial high schools were given a short test of mathematical language. The test was also given to 253 children in two international primary school children. The test questions are reproduced in the Appendix.

In terms of student performance, the two main results to emerge from this study were that, (a) where direct grade to grade comparisons could be made, the international primary school children always out-performed the community school children, and (b) performance of both groups improved with schooling but at vastly different rates, so that the gap in performance widened rather than narrowed with schooling (see Figure 1).

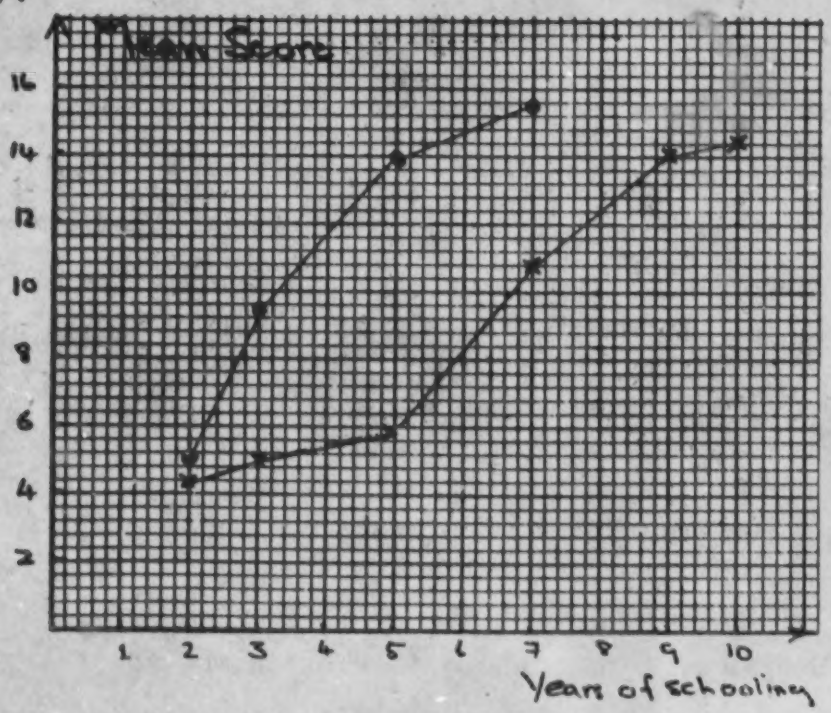


FIGURE 1: Mean scores for Community and Provincial High school children x, and for International school children 0, plotted against years of schooling.

The first of these results was not unexpected in that the test language, English, is a second language for the children in the community provincial high school, while it is the mother tongue of the vast majority of children in the international primary schools. This is consistent with findings elsewhere that bilingualism can significantly affect performance in problem arithmetic (see, for example, Macnamara, 1967). The second result was not so expected and particularly disturbing from an educational point of view. Given that the majority of PNG children enter school with little or no knowledge of English, an initial retardation in language based skills in mathematics is to be expected. What is not expected is the only minimal improvement in these skills for the three years or so after the child first learns to read with any fluency. In contrast, this is a period of very rapid improvement for the children in the international primary schools.

An analysis of the responses given by the PNG students during this period of relatively slow improvement in performance showed that a large proportion of the incorrect responses were not random but formed part of a clearly definable pattern (Jones, 1981b). The present paper seeks to explain this pattern in terms of reading proficiency.

SOLVING WORD PROBLEMS

A critical step in solving a word problem in arithmetic is translating the problem statement into a symbolic statement that can be solved by the appropriate arithmetic process. In

some cases there is one to one correspondence between the words or a group of words in the problem statement and the symbolic statement which allows direct translation. However, in general, this is not the case. In such cases the child has to deduce, from the statement, the underlying mathematical relationship. This requires more than knowing the meaning of individual symbols, words or phrases in isolation. They must also be understood in the context of the problem. This requires a higher degree of reading proficiency than simply making a one to one correspondence.

WHAT DETERMINES READING PROFICIENCY?

Reading brings together both visual and non-visual information. (See for example, Smith 1978). The visual information is the print of the text, the non-visual information is the knowledge the reader brings to reading and includes knowledge of the symbols and letters and the way they go together to form words, and knowledge of the subject matter. Reading is a discrete process in that the brain is not continuously receiving visual input. Rather it occurs in a series of fixations each of about $1/5^{th}$ of a second duration. Of this time about $1/25^{th}$ of a second is spent in receiving the visual information. The other $4/25^{th}$ of a second is spent in trying to make sense of what is received and directing the eye for the next exposure. This occurs in what is known as short-term memory. Unfortunately the capacity of short term memory is limited to about four or five random letters or symbols, about two unrelated but familiar words (10-12 letters) and a meaningful

phrase of four to five words (about 25 letters)[1].

The more non-visual information that can be brought to reading the less reliance there is on the visual information. The less non-visual information, the more reliance there is on the printed material and the less information that can be processed meaningfully in short-term memory. Thus a child whose knowledge of the language is such that he or she can only process one or two words per fixation is unlikely to be able to correctly determine relationships between elements in a mathematics problem that requires a minimum of four or five words for expression. As a result, proficiency in reading, as far as solving arithmetic word problems is concerned, would seem to be related to the number of words that can be processed per fixation. This in turn is related to the speed with which the reader can read a statement. Thus a person who can only read very slowly is likely to be at a severe disadvantage in solving word problems in arithmetic.

CONSEQUENCE OF SLOW READING

A child who processes written sentences word by word is unlikely to be able to determine relationships between the problem elements unless the relationship is determined by a single word which can be processed in isolation. For example, in the question *'Which is more, 10 or 15?'* the

1. The term 'word' should be understood in a very general way. It could consist of a sequence of words which is sufficiently meaningful to the reader to be stored as a single chunk of information.

mathematical relationship can be determined (with a bit of insight) by a child who is limited to word by word processing and knows that 'more' means 'bigger'. However, a question like *'What number is 1 more than 5?'* cannot. The child must be able to process a minimum of 2 words ('1 more') in a fixation to determine the relationship unambiguously. A child who can only process word by word, is likely to give the answer '5' because 'more' means 'bigger' and '5 is bigger than 1'.

Finally, a question such as *'The number 8, is 2 more than what number?'* requires the processing of at least 3 words ('is 2 more') to determine the relationship. A child who can process only one word at a time is likely to answer, '8' because '8 is bigger than 2', while a child who can only process two words at a time is likely to answer 10, because '2 more' means 'add 2'.

COMPARISON WITH DATA

If reading proficiency is a major factor in determining whether or not a child can solve a word problem in arithmetic, then what pattern of responses would be expected for the questions analysed in the previous section.

For the question 'Which is more, 10 or 13?', provided a child can read and understand each word individually, and knows about the relative size of the numbers 10 and 13, then the child should be able to answer the question correctly. Experience has shown that children from grade 2 on in the

community school system generally have these prerequisites. Consequently it is expected that the majority of children would be able to answer the question correctly. Further more, it is expected that there would be little improvement with further schooling and this is in fact observed (see Figure 2). The response pattern for the international primary school is almost identical and is not shown.

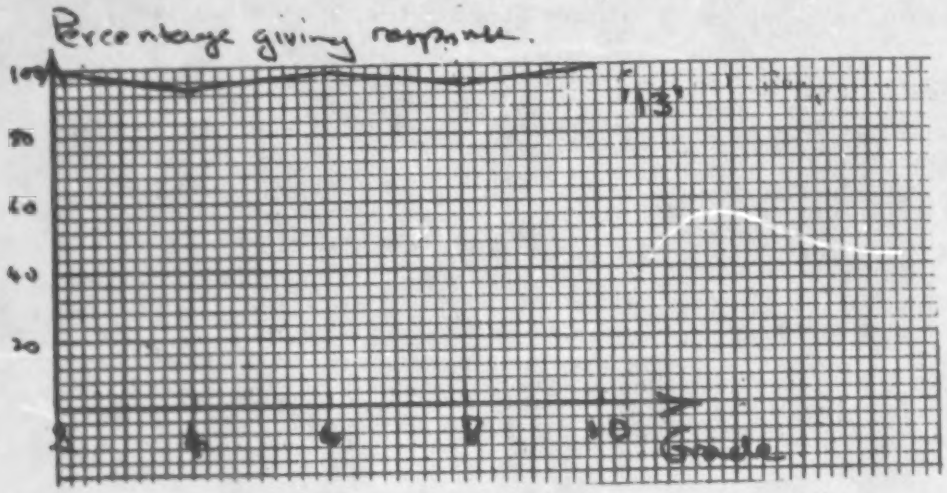


Figure 2. Percentage giving correct response to the question in 'Which is more, 10 or 13?' for the community school and national high school children, by grade.

For the question, 'What number is 1 more than 5?', the additional requirements over and above the previous question are that the student can add 1 to 5 (or 'count on 1'), a skill possessed by almost all the second graders in community schools, and a reading proficiency sufficient to identify the underlying mathematical relationship. A child who can only process the problem statement 'word by word' would be expected to give the incorrect answer '5'. It is also expected that the proportion of children giving this response would decrease with schooling as general reading proficiency improves, with a consequent improvement in the proportion of

children giving the correct response. This is in fact observed in both school systems (see Figures 3 and 4). For the children in the community schools (Figure 3) about 60% in grade 2 give a response characteristic of 'word by word' processing and this decreases to about 20% in grade 6. There is an almost complementary increase in the proportion giving the correct response.

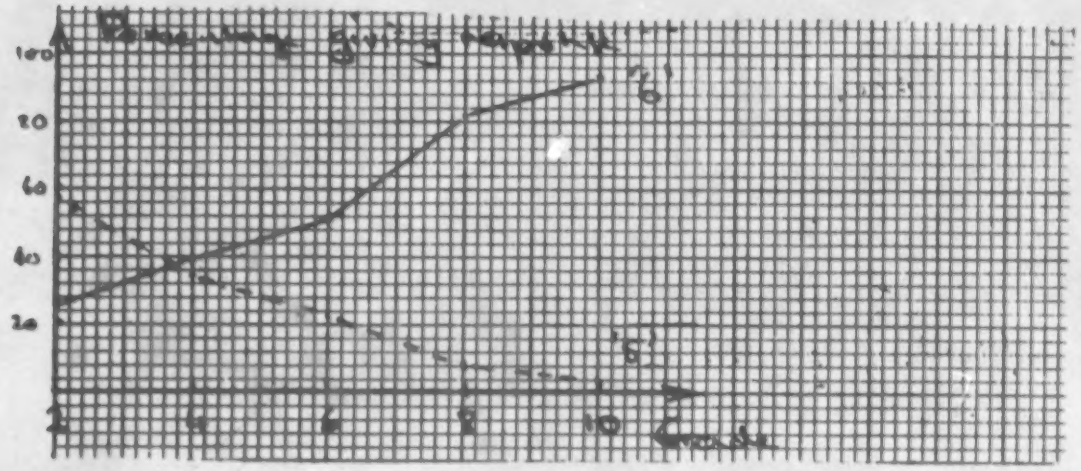
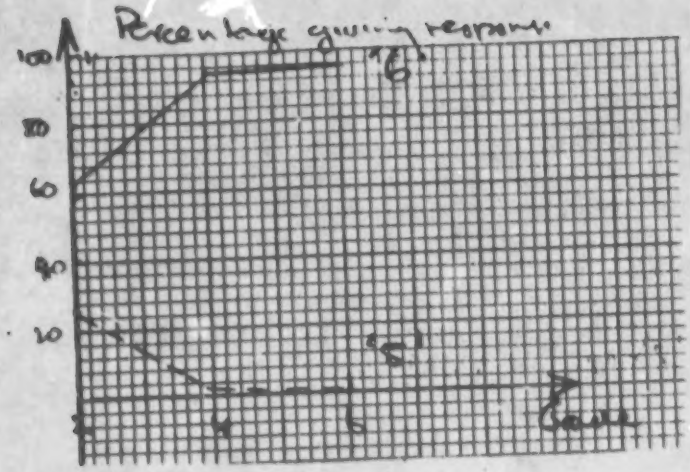


Figure 3. Percentage giving incorrect response '5' (--) and correct response '6' (——) to the question 'What number is 1 more than 5?', for children in community and and provincial high schools, by grade.

For the children in the international primary schools (Figure 4) only about 20% give a response characteristic of 'word by word processing' in grade 2 and this response all but disappears by grade 4. Again there is a complementary increase in the proportion of correct responses.



Figre 4: Percentage giving incorrect response '5' (--) and correct response '6' (_____) to the question 'What number is 1 more than 5?', for children in international primary schools, by grade.

The pattern of responses for both groups of children is qualitatively similar. However, there are significant quantitative differences. Firstly, in the proportion of children initially restricted to 'word by word' processing, and secondly, in the period of time for which this level of processing persists.

For the question 'The number 8 is 2 more than what number?', identification of the underlying mathematical relationship requires the child to be able to process at least three words at a time. Having done that, the child needs to be able to subtract 2 from 8 (or 'count back' 2) to solve the problem. Such computations are generally within the capacity of the second graders in both school systems. Given the pattern of responses to the previous question by the community school children, it would be expected that a large proportion would

give the response '8' which is characteristic of 'word by word' processing. Of those able to correctly answer the previous question, a proportion would be expected to be limited to processing two words per fixation and would respond accordingly giving the answer '10'. With further schooling and improved reading proficiency, the proportion giving the response '8' should decrease, with a subsequent increase in the proportion giving the incorrect response '10', and eventually an increase in the proportion giving the correct response '6'.

This pattern of responses is in fact observed for both groups (see Figures 5 and 6). For the community school children at grade 2 level, about 45% give the incorrect response '8' and this decreases to about 17% at grade 6. These are the children restricted to 'word by word' processing. The second incorrect response '10', which is given by children restricted to processing two words per fixation, makes up about 20% of responses at grade 2 level. This increases to about 30% at grade 6 before decreasing to about 10% in grade 10. The proportion of incorrect responses increases with the combined phasing out of the incorrect responses '8' and '10'. See Figure 5:

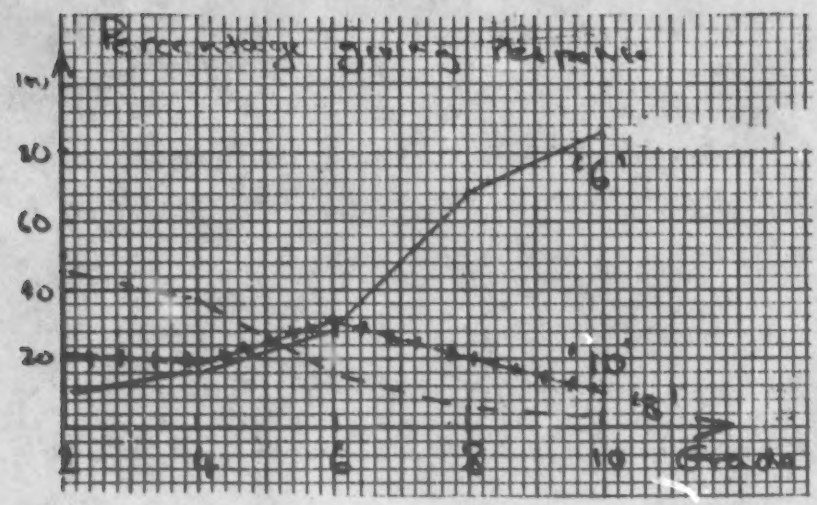


Figure 5: Percentage giving incorrect responses '8' (- - -) '10' (+ + +), and the correct response '6' (____) to the question 'The number 8 is 2 more than what number?', for community and provincial high schools by grade.

For the children in the international schools (Figure 6), only about 17% give the response '8' at grade 2 levels and this response all but disappears by grade 4. About 18% give the response '10' at grades 2 and 4 but by grade 6 it has all but disappeared. The proportion of correct responses increases with the combined phasing out of the incorrect responses '8' and '10'.

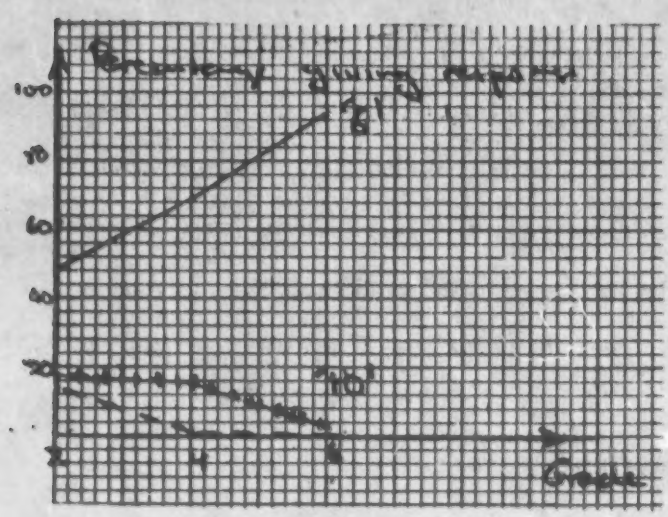


Figure 6: Percentage giving incorrect responses '8' (----), '10' (+ + +), and the correct response '6' (———), to the question 'The number 8 is 2 more than what number?, for international school children, by grade.

Again the distribution of responses is similar for the two groups but there are significant quantitative differences in the proportion of students of children in grade 2 apparently restricted to one or two word processing, and the period of time for which these low levels of reading proficiency persist.

Although the present analysis has been restricted to three questions from the Language and Mathematics Test, similar patterns of responses are found for all questions on the test involving 'more' and 'less'.

DISCUSSION

Despite the fact that reading profiency increases with schooling in both school systems, the reading proficiency of many

community school children is still highly limited by the time they enter secondary schooling. For instance, at the grade 6 level, approximately 50% of students do not have the reading proficiency necessary to determine mathematical relationships requiring 3 words for specification, while around 20% do not even have the proficiency to determine relationships which require 2 words for specification. In this regard they lag significantly behind their contemporaries in the international schools.

Given that the community school children are reading in their second language, some lag is to be expected. Unfortunately, the lag is reinforced by two factors.

One is that the children grow up with languages which have no well established written tradition. As a result, the idea of representing language symbolically is new to many students entering community school and is not reinforced during schooling by the home environment. This is in direct contrast to the experience of the majority of international school children who grow up in an environment in which they are bombarded with symbolic representation of language from their very earliest years. One consequence of this is that Papua New Guinean school children may be fluent in their 'tok ples' or 'tok pisin' and yet no more proficient in reading these languages than in reading English.

Secondly, when compared to international schools, community schools are generally poorly equipped with reading materials and community school children generally have little or no

access to written materials outside the classroom. They grow up in what might be termed a 'non-print society'. Even if they did have access to reading material in English, only the tiniest minority would have parents or relatives who could help them practise their reading skills outside school. By contrast, in the international schools considerable emphasis is given to developing reading skills from the very start of schooling, with children being encouraged to take books home on a regular basis and parents are expected (and are able) to assist with the development of reading skills.

A consequence of the above is that children in the community schools start off behind their English speaking contemporaries in international schools and fall even further behind in the early years of schooling. Also, given that the language demands of the community school mathematics syllabus closely parallel those of the international school syllabus, there is every chance that the average community school child's English language capabilities, especially his capacity to read the language, will not match the language demands of the curriculum and he or she will fall progressively behind in achievement. The observations of Roberts (1979) would seem to support this.

CONCLUSION

The pattern of responses given to the questions discussed are as would be expected of children with variable, and, in many cases, a highly limited English language reading proficiency. However, at present, the link between reading proficiency and performance on word problems is only hypothetical. If a

definite link can be established then it would suggest that little improvement in the quality of mathematics learning in community schools can be achieved without a considerable emphasis on improving reading skills, a somewhat daunting task.

REFERENCES

JONES, P.L.: 1981a, 'Mathematical Language and the Learning of Mathematics in PNG', MEC Report No.16, Lae, PNG, Mathematics Education Centre, University of Technology.

JONES P.L.: 1981b, 'Learning mathematics in a second language: a problem with 'more' and 'less'', to be published.

MACNAMARA, J.: 1967, 'The effects of instruction in a weaker language', Journal of Social Issues, 23 (2), 121-135.

SMITH, F.: 1978, 'Understanding Reading', (New York: Holt, Rinehart and Winston).

ROBERTS, R.E.: 1978, 'Primary Mathematics in Papua New Guinea', Papua New Guinea Journal of Education, 14, 201-216.

LANGUAGE AND MATHS TEST

1. Which is more, 10 or 13?
   Answer:

2. Which number is 1 more than 5?
   Answer:

3. John has 5 fish and Bill has 7 fish. Who has more fish?
   Answer:

4. Patrick has 2 more fish than Christopher. If Patrick has 8 fish, how many fish does Christopher have?
   Answer:

5. The number 8 is 2 more than what number?
   Answer:

6. What is 3 more than 6?
   Answer:

7. Which is less, 7 or 9?
   Answer:

8. Which number is 2 less than 5?
   Answer:

9. Mary has 7 shells and Margaret has 3 shells. Who has less shells?
   Answer:

10. Anne has 3 less shells than Gertrude. If Anne has 5 shells, how many shells does Gertrude have?
    Answer:

11. The number 6 is 2 less than what number?
    Answer:

12. What is 3 less than 5?
    Answer:

13. My pencil is 8cm long. John's pencil is 2cm shorter than mine. How long is John's pencil?
    Answer:

14. My stick is 15cm long. Bill's stick is 13cm longer than mine. How long is Bill's stick?
    Answer:

15. It is now 2.00 o'clock. What time will it be in 2 hours time?
    Answer:

16. It is now 5.00 o'clock. What time was it 3 hours ago?

17. A trade store is open from 1.00 p.m. to 4.00 p.m. For how many hours is it open?
    Answer:

NURSES AND MATHEMATICS

SUSAN PIRIE

SHELL CENTRE - NOTTINGHAM UNIVERSITY

The brief for this seminar was: 'to encourage the flow of information about mathematics education in Papua New Guinea'. My paper may therefore be a little atypical of the general run of the papers being presented. For the past three years I have been working in England on a project to analyse the mathematical problems encountered by a nurse in her* work, and then to devise some remedial system to help her. I have been extremely fortunate to have been invited by Phil Clarkson to look at the work being done in the Mathematics Education Centre in this field.

I intend therefore, to describe in some detail the research methods I have been using with British nurses and indicate how I hope to use the results thus gained to the advantage of nurses in Papua New Guinea.

To generate findings which would assist the training of future learner nurses it has been necessary to answer 4 questions:

1. What mathematical skills are needed by a nurse?
2. Which mathematical fields cause the most common areas of difficulty?
3. Are the learner nurses aware of their problems?
4. How can remedial help best be given?

One fact of paramount importance, which was apparent from the start, was the absence of any formalised mathematics curriculum across the schools of nursing and the complete absence in many areas of any timetabled mathematical teaching at all. This was both an advantage and a disadvantage. It meant that everywhere I went I was welcomed with open arms. Tutors were frequently prepared to admit that they were unwilling to teach mathematics because their own skills were, at best, shakey, and in many cases, seriously lacking or even incorrect. They were desparate for any help which would take the burden of worry - and, in some cases, guilt - off their shoulders.

It also meant, of course, that I had to spend a great deal of time in the field compiling a list of the mathematical skills which a nurse needs. There was a marked dichotomy between real need and need as the

* Throughout this paper 'her' will be taken to mean 'him or her'. In England we are no longer allowed to specify the sex required of applicants for jobs.

tutors perceived it. This was caused partially by the situation where non-clinical tutors no longer work regularly on the wards and are thus out of touch with some of the changes brought about by the introduction of the Systeme International (S.I.) Units and by new forms of drug packaging.

To answer question 1, therefore, I spent several weeks on a variety of wards, observing the nurses at work and interviewing both learner nurses and trained staff. The spin-off from my observations was that I was able to see how the nurses actually did their calculations when in a work environment rather than a test situation. It enabled me, too, to get some idea of the areas of difficulty and the nature of the thinking which produced their errors. I then held interviews and informal conversations with various nursing tutors from 3 schools of nursing and studied the returns of a very detailed follow-up questionnaire put to half of them.

A literature search produced only 3 books in England designed to teach maths to nurses. In addition to these, I also studied the clinical medical text books recommended to learners on nursing courses, and analysed over 2,000 final nursing examination questions.

Based on these findings I compiled a list (see section S appended at end) of the skills which a nurse will be called upon to use and the upper bonds of difficulty expected in each topic.

The next step was to define the problems areas. A sample of around 550 nurses was selected to cover the range of educational and social backgrounds and the stages of training which exist within the total group of learners in England. This sample group of learners was given a mathematical multiple choice diagnoistic test covering the topics and mastery levels established in stage 1 (see section II). Analysis of these tests threw up some very low scores in certain topics and it was apparent that remediation was essential in various fields if the nurse was to be able to work safely with patients.

I shall digress a moment to describe the British system of nurse training. There are approximately 200 schools of nursing in England and each sets its own levels of entry qualifications. On average this is 3 or 4 subjects at G.C.E 'O' level standard, one of which must be English language ('O' level is an examination taken at 16 years of age.) Only 4 schools of nursing ask for mathematics 'O' level too. A girl may not,

however, start her nurse training until she is 18 years old. This rule is laid down by the General Nursing Council since they consider that a mature attitude towards pain and patients is necessary. Once on the course, learners are involved in a cyclical form of training. They spend a 4-6 weeks 'block' initially in the school of nursing, then 2-3 months on a ward, a 2-3 weeks 'block' back in school, 2-3months on a ward, etc.

Both the 2 year age gap and the cyclical training programme have very significant implications for a nurse's academic learning. The training programme demands that a nurse be mathematical competant by the end of her introductory 'block' since she will then be actively involved with caring for the sick and may meet any of the problems which occur in the daily life of a nurse. This indicates that help must be given prior to a learner's first day on a ward. A young person leaving school at 16 can suffer a considerable loss in mathematical, especially computational, skills during the 2 years prior to commencement of training. It was this fact which led me to concentrate on remediation at entry to the training course, rather than to make recommendations to schools.

Obviously, the 4-6 weeks of the introductory course are already fully spoken for in terms of timetabled learning time in all the schools of nursing. This, together with the definite reluctance and inability of tutors to mount a taught maths course, indicates that help can only realistically be given in the form of self-help materials. These materials will only be effective however, if the nurse is aware of her mathematical short-comings. This leads one to ask question 3, "Are they aware of their problems?".

The selected sample group mentioned earlier was given a list of topics (see Section I) and asked to assess their own capabilities on a 4 point scale. They were totally unaware that they were then going to be asked to actually do a test on these topics. The results were fascinating! There was no correlation whatsoever between their predicted and real scores. They neither consistently over nor under-rated their abilities. The conclusion therefore was that all learners would need to be given a test on entry to training to make them aware of their own problem areas.

The aim of my research is essentially a practical rather than hypothetical one: to help nurses become safer and more accurate in their use of mathematics on the wards. Therefore, to answer question 1, "How can remedial help best be given?", I was seeking a method of remediation which, although not necessarily the ideal method from the view

of pure research, would be the most effective given the constraints of time and time-tabling under which nurses are taught.

Unfortunately, no self-help materials existed, so my task was then to write the necessary materials. I had two constraints:

i) the materials had to be motivating - attractive to look at easy to read, and in no way reminiscent of school text books,

ii) they had to be obviously relevant to nursing as opposed to life in general.

I settled on the format of individual booklets, each on a single mathematical/nursing topic. The layout is spacious with occasional illustrations and the work is presented with frequent 'Checks' (not 'tests') to reinforce the learning taking place. The student is recommended to work for only 10 to 15 mintues without taking a break. All the examples used are taken from normal ward experiences, and the nurse can thus relate the maths to the practical field of her career interests.

How does this affect the Papua New Guinean Nurse?

It has been stressed to me that the lack of mathematical abilities in nurses here is beyond my gloomiest fears. This may be true - so was the inability of 62% of one set of learners in an English school of nursing to calculate the total number of pills needed by a patient required to take 1 tablet 3 times a day for 4 weeks!

I hope, while here, to be able to identify the areas of mathematical competancy required by a Papua New Guinean nurse, and to look at methods of teaching and remediation appropriate to her needs. It would be rewarding if I were able to adapt the materials devised for British nurses, but the next few weeks will tell whether I have, in fact, to throw all these ideas out of the window and begin afresh!

My basic philosophy is that learners will only learn if they are motivated and so all mathematics must be presented as relevant. Where understanding cannot be achieved then the nurses should be given at least (or at most?) some basic techniques to fall back on. Of higher priority even than this, however, is the need to arm every nurse with this shield:

1. Ask yourself "Is the answer reasonable?" (10 pills before each meal is not reasonable!).

2. If in any doubt - ask someone else (and it is hard to expose one's ignorance in this way).

This protection for the patient will only be effective if tutors and senior nurses are sympathetic to a learner's insecurities and help to build up her confidence to ask for help. Students the world over develop techniques for giving the answer they think the tutor expects, or for boosting a lecturer's ego by appearing to understand. In a profession where human life is at stake these tricks must be discarded. There must be no shame attached to asking for help. An engineer who makes a mistake may damage valuable tools and waste costly materials. A nurse who makes a mistake may kill someone.

LANGUAGE AND MATHEMATICS AT TERTIARY LEVEL

MARTIN REED

MATHEMATICS DEPARTMENT

PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

Introduction:

The field of interaction between language and mathematics education is a complex and varied one; a comprehensive review is given in Austin and Howson's (1971) state-of-the-art paper. Here I would like to concentrate on the issues relating to a student at the tertiary level of education (taken here to mean "A"-Level to pass degree in U.K. terms or the level of work at P.N.G.U.T.), learning mathematics in English although this is not his first language. There has been little published research in this area compared with work at the primary and secondary education levels, and those results that have been obtained tend to contradict conclusions drawn from experience at earlier levels. In order to try and explain these differences, I should like to consider three types or categories of mathematical activity:

Category A: Language comprehension

Category B: Concept formation

Category C: Mathematical symbolism

(These categories are similar to the three levels proposed by Nesher & Teubal, 1975). In solving a problem or learning a technique in mathematics, the type of mental activity we engage in typically progresses from A to B to C:

Type A involves reading the text of a problem or the explanation of a technique, understanding it as ordinary language; type B involves perceiving the underlying mathematical concepts or relationships; and in type C activity we perform translation of our thoughts into mathematical symbols and notation and the subsequent manipulation of these symbols to obtain the required result.

Clearly, acitivity of type B (usually illustrated in strip cartoons by a light bulb flashing above the subject's head) is the central part of all mathematical learning and problem-solving processes - it is also the most intangible. But the relative importance of the other two types will depend on the level of mathematical development. At the earlier (primary and secondary) levels, there is comparatively little creation and manipulation of symbols (most type C activity is with numbers), and the major concern is with the comprehension of textual explanations and word - problems. On the other hand, at the tertiary level texts and problems are increasingly written in the language of mathematical symbolism, and substained symbolic interpretation and algebraic manipulation (type C activity) is required, while the students' longer experience with the English language should lessen problems in type A comprehension.

This description is of course a simplification of the reality, but it will serve as a useful structure in which to discuss the issues involved.

In this paper I should like to review the areas of language-mathematics interaction under the headings of category A, B and C activity. I will then briefly consider the statistical results from three recently-published investigations, and make some suggestions as to possible directions for future research.

Category A: Language Comprehension

Here we are primarily concerned with the readability of the teaching material. This is likely to be affected by the closeness of the student's first language to English; it may be:

(i) a 'dialect' of English (e.g. Jamaican, P.N.G. English)

(ii) an Indo-European language (e.g. German, Russian)

iii) a 'non-Western' language (e.g. Japanese, tok ples)

Strevens (1974) has pointed out the advantage possessed by speakers of Indo-European languages over those of non-Western tongues, in the possession of the Greek-Roman system of prefixes (pre-,post-,co-,mono-, etc) and suffixes (-or, -ant, -ize, etc) or direct translation equivalents of them. (The deeper question of to what extent the structure of mathematics itself has been influenced by the syntax of the Indo-European language group, will be mentioned under the heading of category C). Students in P.N.G. are in an ambiguous position, in that their first language will be non-Western, but they will most likely also be fluent in Pidgin. While Pidgin draws the majority of its vocabulary from English, it has not borrowed the prefix-suffix framework. Apparent fluency in spoken English may therefore mask a lack of the background linguistic structure we take for granted, and which is of particular importance in mathematics and science.

A very popular tool developed by linguists for assessing the readability of a text, is the cloze procedure (Taylor, 1953). In this, subjects from the target audience are given passages from the text with words deleted at fixed intervals (commonly, every sixth word is replaced by a blank). The text's readability for the subjects is then measured by their score in correctly filling in the missing words. This procedure has other uses: it may be treated as a test of the subjects'

comprehension, and also as a teaching tool. When used to test the reader rather than the text, there arises the question of exactly what language skills are being tested.

At the primary school level, strong correlation has been reported between children's scores on cloze test, other language comprehension tests and mathematics achievement tests (see for example, Hater and Kane 1975, and Kossack 1976,).

A text may be made more readable by restricting vocabulary, shortening and simplifying sentences, using active rather than passive constructions, etc. There are dangers in the language thus becoming too artificial, however. Floessner (1974) suggests that some German 'new maths' primary-school texts create selective language barriers in children's minds. Nesher & Teubal (1975) show that children can gain the misconception that certain words function as verbal clues (e.g. that 'more' always means addition); using their three-level structure, they attribute these errors to an attempt on the part of the teachers or the children to pass from level A to level C activity without going through level B. Artificiality of language may also lead to poor student motivation.

An alternative approach to improving type A comprehension is to provide specilized instruction in English, as occurs in the language courses in P.N.G.U.T. for instance.

Category B: Concept Formation

To what extent is thought dependent on language? Is thought simply 'speech minus sound', or does it rise above language to become 'thinking in pure meaning'?
Vygotsky (1962) concludes that language is inextricably involved in thought: "the concept does not attain to individual and independent life until it has found a distinct linguistic embodiment". Austin & Howson (1979) remark that mature

thinkers often need to talk aloud to a colleague (who is usually not expected to reply!) in order to collect their thoughts on a tricky problem.

If this is the case, does the nature of the language used affect the nature of the thought-processes themselves? Such is the linguistic-relativity hypothesis proposed by Whorf (1956). It has been supported by research on mathematics learning in communities speaking their own tribal languages. The most detailed study published describes Gay & Cole's (1967) work among the Kpelle of Liberia; similar experiences in P.N.G. have been reported by Philp (1973). They have found that, in Philp's words, "the structure of the language determines the kind of classifications available to children and hence to a large extent the nature of the concepts they form". Western culture gives expression to its concept and classification system in the science of formal logic. Anthropologists too have concluded that "it begins to look as though formal logic as we know it, is an attribute of the group of Indo-European languages with certain grammatical features" (Bridgman, quoted by Austin & Howson).

Do we then infer that students from non-Western cultures will be unable to 'do maths'? Here I think we must distinguish the meta-language of logic (type B thinking) from the language of mathematics (type C). Such students will still be able to solve problems - the trouble comes when we ask them to explain how they have reached their answer. As explanation, we expect a reasoned argument, in our Western language of deduction, counter-example, contrapositive, etc. The point is strikingly illustrated by Gay & Cole: 'One of the ubiquitous findings in our experiments is that Kpelle subjects had great difficulty when asked to explain the reason for an answer or to state the general rule underlying the solution of a problem... ...Moreover, after giving such a description, the same Kpelle person who had identified the concept would often no longer make correct responses."

Even in our own culture this is observed. Thom (1973) vigorously attacks the attempt of some varieties of 'modern maths' to teach through the explicit definition of the underlying structure instead of through use. This is echoed by Henkin (1972) with reference to the introduction of symbols. Indeed, some 'correct' explanations in modern maths are tautologous when taken at face value (For example, "2 x 3 = 3 x 2 because the operation of multiplication is commutative").

Category C: Mathematical Symbolism

Mathematical English is not so much a language as a collection of symbols, conventions and notations embedded in English - but English used in a special way. Kane (1968, 1970) has pointed out how Mathematical English (ME) differs from Ordinary English (OE):

(i) ME is almost totally non-redundant, except at primary level.

(ii) Many words and phrases have a specialized meaning in ME distinct from their OE meaning (e.g. similar, normal, limit, one-to-one).

(iii) Grammar and syntax are less flexible in ME than in OE.

(iv) Some parts of speech, such as adjectives, are less frequent in ME than in OE; others, such as nouns, are more frequent.

(v) Often the most important part of an argument in ME will be stated using symbols.

For these reasons Kane questioned the validity of applying to ME texts the readability tests designed for OE. However, Hater & Kane (1975) have adapted the cloze test to deal with symbols as well as words, and have obtained good results, as

mentioned earlier. These applications, however, have been to primary-level texts where there is usually a one-to-one correspondence between symbols and the words used to vocalize them (e.g. "4 x 3 + 2 = 14"). The application of the cloze procedure to lexical items such as $\sum_{i=1}^{n} a_i x^i$ is less straight-forward. At higher levels also the low-redundancy of ME would make it very difficult to predict missing words/ symbols. This is because of the density of content in ME; reading an ME text necessarily involves the reader continually referring back, rereading, varying his reading speed and "conversing with himself" (Brunner 1976).

Cheong (1978) analysed the reading comprehension skills needed on first-year degree level texts in dynamics, statics, physics and chemistry. The dynamics text (the most mathematical) "basically requires the development of the ability to see thought-relationship patterns, especially of the logical-deductive type." In addition there is a need to "identify repeated lexical items or structures for the clarification of restated ideas which are parallel to the main idea." The passive construction is used more frequently in the mathematics-related texts (frequencies of 40% in statics, 27% in dynamics, 20% in dynamics, 20% in chemistry, 16% in physics). In other ways, though, the statics text required quite different skills from the dynamics text.

In view of all this, I feel that for tertiary-level ME texts the cloze test is unsuitable as a measure of student comprehension. It is impossible for a student to comprehend the text in language terms (category A) without engaging in considerable mental activity of types B and C - results from a cloze test will therefore depend on a wide range of linguistic, conceptual and mathematical factors.

An interesting question is the extent to which the syntactical structure of the Indo-European language group has influenced the concrete symbolism and syntax of ME. Morris (1978) gives examples of the circumlocutions needed in non-Western languages

to translate mathematical terms. There are important areas in which English itself is inconsistent with mathematical notation, however. Consider the use of 'any' to mean 'some' or 'all' ("This is true for any x", "Is there any x for which this is true?"), and the ambiguous use of 'or'. Interestingly, the Kpelle language has separate ways to express the 'inclusive or' and the 'exclusive or', and Gay & Cole found that Kpelle children performed better than an American peer-group on a learning task on this topic, Again, the learning of division is plagued by the subtle differences between '4 is divided by 3' and '4 is divided into 3'. Morris (1974) gives many more examples.

In a more general sense, ME also differs from OE in the structure of its arguments. In a literary work, the bare outlines of the subject are given initially, and then new facts and events are brought in throughout the text to build up a full picture. In an ME text all the facts will be declared initially (in statements of the form "Let p and q be integers, and let ..."). These facts are then manipulated and reworked throughout the text, eventually being combined and simplified to the required conclusion.

Experimental Findings.

Comparatively few studies have been made at tertiary level in this field. Here I would like to cite the results of three investigations. All of them measured the correlation between various language skills and mathematical achievement for students at the post - '0' level stage (1st year PNGUT), learning in English as a second language; two of the studies were conducted in a developing country in Africa.

I

Investigation I was by Reed and Wainman (1978) at the University College of Swaziland. As subjects they took the first-year Science students (N ≈ 50). The tests they gave were:

(i) a cloze test on an ME text containing few symbols.

(ii) a language comprehension test on an ME text.

(iii) a mathematics test with short 'mechanical' questions.

(iv) a maths test with more extended reasoning and word-problems.

The language test (ii) was further divided by considering separately the questions requiring rephrasing of sentences. The correlation coefficients they obtained are given in table 1.

		(i)	(ii)	(iii)	(iv)
(i)	cloze				
(ii)	comprehension	0.23			
(iii)	maths 1	0.24	-0.40**		
(iv)	maths 2	0.27*	-0.10		
rephrasing				-0.43**	-0.33**
other				-0.20	0.12

**p<0.01 *p<0.05

Table 1: Reed & Wainman (1978) - correlation coefficients

Notice that the cloze test did not correlate significantly with either the language test or the mathematics tests. Notice also the significant negative correlation between performance in the language test (ii) and performance in the 'mechanical' maths test (iii). I would suggest that the language test is testing type A thinking, while the maths test involves almost purely type C activity. The other maths test (iv) has a much smaller negative correlation with language performance, either because understanding of the test questions required language (type A) skills, or because the more extended ME writing required bears a similarity to some language skills (it is surprising, then, that rephrasing skill - which one might compare to manipulation of equations - correlates negatively with mathematics performance).

II

Investigation II was was by Turner (1980) at the R.M.I.T. Technical College in Melbourne. The subjects were 23 first-year students, divided into (a) a group of 10 whose home language was English, and (b) a group of 13 from non-English-speaking backgrounds. (Their home languages included Greek, Italian, Russian; their competency in English varied widely).

The tests were:

(i) Knowledge of mathematical symbols

(ii) Knowledge of mathematical vocabulary

(iii) a mathematics achievement test

(iv) a cloze test on an ME text with both words and symbols deleted. The mean scores and correlation coefficients for the two groups are given in table II.

	TESTS			
MEAN SCORES (%)	(i)	(ii)	(iii)	(iv)
(a) English	69.3	46.0	42.5	60.2
(b) Non-English	67.3	34.2	49.7	43.8

	(a) English			(b) Non-English		
CORR. COEFFTS.	(i)	(ii)	(iii)	(i)	(ii)	(iii)
(i) symbols						
(ii) vocabulary	0.64*			0.62*		
(iii) mathematics	0.66*	0.54		0.39	-0.09	
(iv) cloze	0.69*	0.63*	0.33	0.29	0.49	0.26

Table II: Turner (1980) - mean scores & correlation coefficients

Notice first from the mean scores that the non-English group performed better than the English group in the mathematics test, despite obtaining poorer results in the other tests. If we look at the test correlation matrices for the two groups, we find small positive correlations between the cloze test and the other tests, much as in investigation I. Apart from the correlation between the two vocabulary tests (symbols and words), there is no significant relationship appearing for the non-English group; the English group does show stronger relationships between vocabulary and mathematics scores. A study of this kind, using English and non-English students at the same institution, is particularly valuable; in this case, however, the small size of the groups, the heterogeneity of the non-English group and the restricted nature of the language tests do not support the drawing of further conclusions.

III

Investigation III was by Zepp (1980). In two successive years at the National University of Lesotho, he gave two sets of American language tests to his first-year students, and correlated the results with performance in mathematics courses M101 (algebra trigonometry) and M102 (calculus). The correlation matrices are shown in table III (1978 results appear above the diagonal, 1979 below the diagonal; $31<N<56$).

The various components of the language tests intercorrelate significantly, but there is only small correlation between these and the mathematics tests. The differences in individual correlations from 1978 to 1979, are a warning against reading too much into such results.

Conclusions and suggestions for research

In general the results cited support the relevance of the three category structure of mathematical activity which I have outlined, with the predominance of type C over type A activity at higher levels. The rather inconclusive statistics so far obtained might be improved by considering other variables, as follows.

Co-op tests	1	2	3	4	5	6	7
1. Vocabulary		0.54	0.68	0.44		0.36	0.28
2. Level of Comprehension	0.57		0.78	0.12		0.10	0.08
3. Speed of Comprehension	0.53	0.78		0.22		0.18	0.12
4. Expression	0.50	0.49	0.15			0.36	0.29
5. Total English						0.38	0.35
6. M 101	-0.04	0.01	0.32	0.12	0.06		0.83
7. M 102	-0.00	0.01	0.02	0.03	0.00	0.83	

Celt tests	1	2	3	4	5
1. Vocabulary		0.53	0.39	0.27	0.20
2. Structure	0.53		0.62	0.39	0.30
3. Listening	0.59	0.53		0.29	0.10
4. M 101	0.08	-0.07	0.12		0.83
5. M 102	0.11	0.06	0.20	0.83	

Table III: Zepp (1980: correlation coefficients

There is a clear need to differentiate between various language skills in future investigations, if we remember that the ultimate aim of our work is to design the most effective language tuition we can give to mathematics students. As a complement to this, we should also differentiate between various types of mathematics skills. Possible fields are (i) numerical work, (ii) algebra, (iii) geometry (including graphs), (iv) analysis and logic. Each of these fields is influenced by linguistic structure in a different way, and to a different extent. The extent is also dependent upon the degree of emphasis placed on formal proofs. Do non-Western students find numerical and graphic work easier than algebra or analysis? Does this have relevance to what we decide to teach?

A third variable is the student's method of learning. A student with English language difficulties who concentrates on learning from notes and text books, will be at a disadvantage compared with a colleague who naturally inclines towards learning through discussion and practice.

The distinction between the nature of the interaction at secondary and tertiary levels, could be profitably investigated in a longitudinal study of a selected group over the years of their late-secondary and early-tertiary education. Some of these ideas have been explored in a small pilot study with a group of about 25 second-year Engineering students. From a test on implicit differentiation and inverse trigonometric functions, I should like to consider five questions:

Q.1 short word-questions

Q.2 problems relating angles to side-lengths in diagrams

Q.3 producing a diagram from a textual description

Q.4 proof of a trigonometric identity

Q.5 equations to be differentiated implicitly

(Examples of the questions are given in Appendix A). From what I have suggested above, questions 1, 2 and 3 will mainly involve activity of type A, while questions 4 and 5 will require skill in dealing with symbols (type C). The correlation matrix for the students' results in these questions appears in table IV, and we see that the first three questions form one group, and the other two questions a second group. There is significant positive intercorrelation within each group, but little (mostly negative) correlation between the groups. If we now take the students' marks in their first-year mathematics course MA139, we find that this falls into the second (type C) group. It seems reasonable to conclude that work with numbers, texts and diagrams requires one type of skill (type A), while work with mathematical symbolism requires another (type C) - and it is the latter type which is predominantly needed in tertiary-level mathematics.

The students were then given a short questionnaire. They were asked to rank in order of preference five types of mathematics work (work with numbers, symbols, diagrams, words and discussing problems), and to indicate their agreement/disagreement with the statements 'In solving maths problems I think in English all the time' and 'I find a maths statement in symbols easier to understand than one in words'. Responses were scored on a five-point scale. Correlations with the test questions are shown in table IV.

	Test questions					
	1	2	3	4	5	MA139
test question 1						
test question 2	0.52**					
test question 3	0.40*	0.36				
test question 4	-0.23	-0.13	0.15			
test question 5	-0.01	-0.18	0.24	0.47*		
1st year maths MA139	-0.16	-0.04	-0.12	0.41*	0.53*	
symbols easier to understand	0.18	0.11	0.43*	0.63*	0.44*	0.14
preference for symbols	-0.62**	-0.50*	-0.04	0.50*	0.32	0.25
preference for numbers	0.30	0.02	0.31	-0.15	-0.27	-0.58**
thinking in English	0.05	-0.15	0.06	0.40	0.21	0.20

*p<0.05 **p<0.01

Table IV: Pilot study - correlation coefficients

Not surprisingly, there is a strong positive correlation between the type C questions (4 & 5) and the preference for symbols over words and numbers. Preference for work with numbers is linked more to the type A questions 1 and 3.

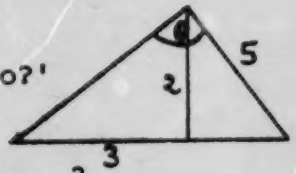
The extent to which a student uses English is his (mainly type B?) thinking does not seem to affect performance on any of the questions except the proof (Q.4)-this would support the posited connection between language syntax and formal logic.

The misconception that "to do maths you have to like working with numbers" is strikingly disproved by the strong negative correlation (-0.58 in the last column of table IV) between the two. It would be interesting to see if this extended to a tertiary-level field, such as numerical methods, with relatively little symbolism (especially as most students did prefer numbers to symbols).

Appendix A Sample questions from test:

Q.1: 'What number has an inverse cosine of zero?'

Q.2: Write θ using inverse trig functions:



Q.4: If $\cos^{-1}x=a$ and $\sin^{-1}y=a$, prove that $x^2 + y^2 = 1$

Q.4: Find $\frac{dy}{dx}$ as a function of x and y: $x^3 + y^3 = 6xy$

REFERENCES

AUSTIN, J.L. and HOWSON, A.G. "Language and Mathematical Education", *Educ. Studies Mathematics*, 10 (1979), 161 - 197.

BRUNNER, R.B. "Reading Mathematical Exposition", *Education Research* 18 (3) (1976), 208 - 213.

CHEONG, L.K. *Syntax of Scientific English*, Singapore, Singapore University Press 1978.

FLOESSNER, W. *Sprachbarriere durch Mathematik*, Neue Unterrichtspraxis, Hanover 1974.

GAY, J. and COLE, M. *The New Mathematics and an old Culture*, New York, Holt, Rinehart & Winston 1967.

HATER, M.A. and KANE, R.B. "The Cloze procedure as a measure of Mathematical English" *Journal of Research in Mathematics Education* 6 (2) (1975) 121 - 127.

HENKIN, L.A. "Linguistic Aspects of Mathematics Education", in Lamon, W.E. *Learning and the Nature of Mathematics*, Chicago, Science Research Associates, 1972.

KANE, R.B. "The Readability of Mathematical English", *Journal of Research in Science Teaching* 5 (1968) 296 - 298.

KANE, R.B. "The Readability of Mathematics Textbooks Revisited", *Mathematics Teacher* 63 (1970) 579 - 581.

KOSSACK, S.W. "A Mathematical Reading Inventory", Ph,D. dissertation, University of Georgia (1976).

MORRIS, R.W. "Linguistic Problems encountered by contemporary curriculum development projects in mathematics" in *Interactions between Linguistics and mathematical education*, UNESCO, Copenhagen (1975).

MORRIS, R.W. "The role of language in mathematics" *Prospects: Quarterly Review of Education* 8 (1) (1978), 73 - 81.

NESHER, P. and TEUBAL, E. "Verbal cues as an interfering factor in verbal problem solving" *Education Studies in Mathematics* 6, (1975), 41 - 51.

PHILP, H. "Mathematical Education is developing countries - some problems of teaching and learning" in Howson, A.G. (ed), *Developments in Mathematical Education*, London, C.V.P. 1973.

REED, M. and WAINMAN, H. "Language competence in mathematics", *International Journal of Mathematics Education in Science and Technology* 9 (1) (1978), 31 - 33.

STREVENS, P. *What is linguistics and how may it help the mathematics teacher?*, UNESCO, Paris 1974.

TAYLOR, W.L. "Cloze Procedure: A new tool for measuring readability" *Journalism Quarterly* 30 (1953).

THOM, R. "Modern Mathematics: Does it exist?" in Howson, A.G. (ed), *Developments in mathematical Education*, London, C.U.P., 1973.

TURNER, R.L. "Language factors in mathematics of students with English-speaking backgrounds compared with those with a non-English-speaking background". *Research in Mathematics Education in Australia* (1980) 1, 201 - 221.

VYGOTSKY, L.S. *Thought and Language*, New York, M.I.T. Press and John Wiley, 1962.

WHORF, B.L. *Language, Thought and Reality*, New York, M.I.T. Press and John Wiley, 1956.

ZEPP, R.A. "Relationships between Mathematics achievement and various English language proficiencies", *Education Studies in Mathematics* 11 (1980) (in print).

THE ROLE OF MATHEMATICS EDUCATION RESEARCH IN PAPUA NEW GUINEA

1981: THE CONSTRAINTS AND THE PRIORITIES

R.E. ROBERTS

PAPUA NEW GUINEA DEPARTMENT OF EDUCATION

Preliminary to my talk this morning there are two things I want to say.
The first is how delighted I am that a conference such as this is at last a reality and am especially pleased that we have two distinguished overseas visitors here with us. The notion to hold such a conference has been with us for sometime (Bryan will remember our initial attempt to promote dialogue on mathematics education at a one-and-a-half-day seminar held at Konedobu in May 1978 - the unedited and therefore unpublished report of which I still carry around in my brief case). We can be grateful to Phil and the staff of the Centre that, by the staging of this conference, another of our ambitions is being fulfilled. We trust the conference will become an annual event on our education calendar.

The second is that I confess to having contrived by the title of my talk to get in early, certain points about research in the developing context generally and about mathematics education research in particular, which I believe will relate to all the research activities reported at this conference.

There are a number of major constraints which affect research - particularly in developing countries - that need to be constantly borne in mind. These constraints may establish disagreeable parameters to a researcher's interests. Research in a developing country does present particular challenges and requires researchers with rather special constitutions. However, the rewards are substantial in that research findings can be of considerable benefit to a great number of underprivileged people.

Another benefit of speaking first, of course, is that I will not be required to "follow" any of the brilliant papers which will follow my humble offering!

My talk will cover these major constraints to research as I see them, I will then cite the areas of research which I believe are of greatest current concern and which therefore recommend themselves for investigation. I owe much of what I have to say in this paper to the wisdom contained in a paper on research in teacher education in developing countries presented by C.E. Beeby, in 1979 to London University's Department of Education in Developing Countries (Beeby 1979).

Research - A contribution to development

I will begin by offering you a purpose for (educational) research as presented by Beeby (1979; 135) which to me best suits the current situation in education in Papua New Guinea.

> ... the purpose of educational research is to help us to understand and improve practice, whether it's in the classroom or in the places where decisions are made on policy and plans.

If one accepts this purpose then it is necessary to consider the current concerns in Mathematics education in Papua New Guinea, principally the attempt to develop relevant viable curriculum and the search for means to improve standards, and to therefore direct research efforts towards the solving of problems related to these concerns.

CONSTRAINTS

A number of major constraints operate, however, which researches need to be constantly aware of. The degree to which these constraints affect a research project will vary according to the nature of that project. The order in which I present them here, therefore, is not a ranking.

Time

The length of time a project takes to reach fruition i.e. produce useable results, may be critical in at least two senses. One, it is almost a truism in the developing context that results needed to assist decision-making, whether in curriculum design, assessment procedure, teacher education, etc, are required "yesterday". In a recent letter from the Principal Research Officer, Bernie Anderson, to John Hayter (Anderson 1981: 2) referring to John Hayter's evaluation of the secondary mathematics curriculum, Anderson illustrated this point by saying:

> There are besieged administrators and harassed educators looking for help. The clients of PNG's education system want to see action now. They want noticeable improvement in what is perceived to be a "decline in standards"

A second aspect of the time constraint is that when a researcher is planning a study - not necessarily a longitudinal study - because of the frequent state of flux of the policy, the manpower, or the materials availability, situation in Papua New Guinea, the intending researcher needs to ensure that whatever support he/she is likely to need can be reasonably assured for the duration of the study.

Manpower and Finance

The time constraint links with two other constraints, those of manpower and finance. The methodology of most studies is subject to manpower and financial constraints. However, the situation facing a researcher in Papua New Guinea, requiring assistance with data collection and analysis may be critical. For example, research data gathered under the Indigenous Mathematics Project has had, to a substantial extent, to be processed (computer processed) in Australia and the United States, despite the presence of adequate computer hardware in Papua New Guinea. People sufficiently

skilled in speedy and efficient computer programming, were not available here. On the other hand the IMP has had considerable data gathering success by using teachers trained as research assistants.

Financial constraints generally are self-evident. Perhaps for the purposes of this talk it is sufficient to say that in developing countries the spending of public monies, through whichever channels such monies may pass, needs double justification. Though we may, all of us here, appreciate the importance of the sound basis for development which research can provide, there are many, who control funds, who will need to be convinced before they can feel justified in releasing scarce funds for research. Such money, they will feel, could be better spent on projects which are more easily identifiable as urgent than is research.

It would seem that such justification should be tied to Beeby's definition of the purpose research in general, and to Papua New Guinea's development ambitions in particular. I will make some suggestions concerning these ambitions shortly.

Culture

This latter point leads to the consideration of the next constraint which I shall call culture. The principal component of this constraint is communication via written English. English is the officially adopted language of educational instruction in Papua New Guinea. It is for most of the people who are responsible for making changes, at best a second language. It would seem imperative therefore that research reports, if they are to be read, understood and acted upon, must be presented succintly and in plain (not to be confused with simplistic) English. Anderson, when offering Hayter advice recently (Anderson 1981: 2), put it this way

> The report (Hayter's draft) is probably too long and detailed to be read by the majority of professionals for whom it was written. It is the same old story; the sad fact that for a large number of committed and concerned people - who work long hours and are the most receptive to new ideas - it is almost impossible to find sufficient space in their lives to read a comprehensive report.

Though rigour demands, and the researcher's anxiety insists, the spelling out of every last relevant detail needs to be left until the report is required by such authorities as require such rigour. Meanwhile, a presentation of the essential details in a short precise and hard hitting report - even though the full study and final report may not at that time be completed - may be of extreme importance to be "besieged" and the "harassed" who otherwise may be required to make decisions in education on far thinner evidence. I believe Dr. Alan Bishop appreciated this problem when he produced both a teacher digestible (Bishop 1977) and a technical report (Bishop 1978) of his study of students' spatial abilities. This communication problem may be far less acute when the research is carried out by a Papua New Guinean national.

One other aspect of this culture constraint, and one which specifically applies to researches from the western world, is the danger of the biasing of reports by the (subconscious) use of western cultural value judgements, perhaps when discussing teaching styles for example.

National Aspirations

This now leads to the consideration of the final constraint I will mention - one which in turn leads back to the definition of research purpose which I offered you to start with, I call this constraint, national aspirations. The reason, I believe, why the Indigenous Mathematics Project (Lancy 1979, Souviney 1980) has enjoyed the support that it has is because the documenting of traditional mathematical ideas and the

whole notion of leading on from the traditional mathematics children bring to school with them, through to the western mathematical concepts and skills they will need in modern Papua New Guinea via appropriate curriculum materials, is in harmony with the feelings and interests of the leaders of a country struggling for its own identity and self-respect.

Research projects ought to attempt to solve problems of current national concern and be sensitive to the ambitions of Papua New Guinean leaders to establish their own identity. With care, that which is in the best interests of Papua New Guinea can also be in the best interests of the researcher.

These five constraints - time, manpower, finance, culture and national aspirations - I believe, constitute the major areas of concern a potential researcher needs to take into serious account. There will be other constraints, I do not doubt, but provided a researcher faces up to these major constraints, his/her proposals would seem likely to be considered favourably.

I feel that in Mathematics education our track record in this respect is good. In recent years researchers have paid attention to concerns in student learning difficulties, (Lean 1976 Clements and Lean 1980); culture and cognition (Kelly and Philp 1975, Lancy 1979, Souviney 1980); language in Mathematics (Dube and Siegel 1980, Jones 1981); specific curriculum content (Bishop 1979, Siford 1981); curriculum evaluation (Hayter 1981); teacher education and classroom conditions (Roberts 1976, Roberts and Kada 1979); pupil achievement (Edwards 1979, Roberts 1981); some bibliographical work (Meek 1978, Lancy 1979).

Current Priority Concerns

The current concern over poor standards - with its emotive and its political factors which may hinder rational approaches to the study of the problem - is clearly the major area

for investigation. Research oriented to addressing the standards issue would not only be well received and supported, I believe, but does in itself provided some extremely challenging and interesting research opportunities. Specific areas of the concern which suggest themselves would include the development of an appropriate curriculum, teacher education (inservice teacher training and distance education), classroom behaviour, cognitive style and the cultural context, and the language/mathematics interface. The mathematics of educational administration - particularly as it relates to the provision of educational materials to schools in remote areas - needs investigation. And perhaps, more innovatively, the relevance and usage of calculators and mini-computers in mathematics education.

Research projects should attempt to provide recommendations for both short term and long term solutions to problems. Recommendations need to be presented in operational terms by providing suggestions not only about what changes need to be made but by providing suggestions as to how those changes may be brought about, giving due consideration to current and anticipated constraints e.g. Siford (1981) on algebra in provincial high schools, spells out specific syllabus related changes which should help to solve algebraic learning difficulties identified by the study.

Conclusion

I have attempted in very brief and general terms to provide what I believe is an appropriate direction for (mathematics education) research in Papua New Guinea today and to focus on some of the major constraints which influence the selection of research problems, research design, the conducting of, and the reporting on, research. The constraints have been isolated for focus of attention but are in reality interwoven in a complex and unstable context. The weighted importance

of each constraint to any individual research project will depend upon the specific nature of that project.

However, if each piece of research - be it large or small - is oriented to assisting the Education Department, the universities and the colleges in raising standards, their work can be professionally, morally, and personally satisfying.

Perhaps I should close by returning to the point that there is an urgency to get valid research results to the "harassed" and the "besieged" amongst education decision-makers; results which will assist them in the making of, often vital decisions, which may affect the lives of school children for many years to come.

Beeby (1979: 135) put it this way:

> Rich countries may be able to wait a long time for rounded and elegant findings, but in developing countries the help must be given more quickly than research workers would wish if decisions are not to be made on weaker grounds than research can provide.

Such results may not constitute the full story of a research effort but they may provide a far sounder basis for decision-making than would otherwise exist.

Beeby liken the urgency of the case for the speedy presentation of research findings to the right quarters to that of the plight of a:

> ...young couple who arrived late for their wedding at the registry office on a Friday afternoon, only to be told that the office was officially closed. Their sad tale of plane and hotel bookings didn't move the registrar, who had his own train to catch, and told them to come back on Monday morning. At which the girl pleaded, "But couldn't you just say a few words to see us over the weekend?" For the administrators, and ministers of education in developing countries, it's going to be a long weekend".
>
> (Beeby 1979: 153)

With the assistance, however, of this Mathematics Education Centre (and one has to wonder - with the exception of Siford's work - what is happening at the UPNG Mathematics Department) the weekend may not be so long.

REFERENCES

Anderson, B. 1981: Letter to John Hayter, Research Branch File PR2-1-1 dated 21/4/81, Department of Education, Port Moresby.

Beeby, C.E. 1979: "Teachers, Teacher Education and Research", in Gardiner (Ed), 1979.

Bishop, A.J. 1977: "On Developing Spatial Abilities", Mathematics Education Centre Report No 4, Papua New Guinea University of Technology, Lae.

Bishop, A.J. 1978: "Spatial Abilities in a Papua New Guinea Context", Mathematics Education Centre Report No 2, Papua New Guinea University of Technology, Lae.

Clements, M.A. and Lean, G.A. 1980: "Influences on Mathematical Learning in Papua New Guinea: Some Cross-Cultural Perspectives", Mathematics Education Centre Report No 13, Papua New Guinea University of Technology, Lae.

Dube', S.L. and Siegel, J. 1980: "Teaching Mathematics English: Does it Make a Difference in the Learning of Mathematics?", University of Technology, Lae.

Edwards, A. 1979: "Preliminary Report on the Basic Skills Arithemetic (sic) Test Carried Out in Post-Secondary Institutions in Papua New Guinea in 1979", Mathematics Education Centre Report, No 6, Papua New Guinea University of Technology, Lae.

Gardiner, R. 1979 (Ed): "Teacher Education in Developing Countries - Prospects for the Eighties", Department of Education in Developing Countries, University of London.

Hayter, R.J. 1980: "The High School Mathematics Curriculum in Papua New Guinea - An Evaluation Study", Research Monograph, School of Education, University of Bristol.

Jones, P.L. 1981: "Mathematical Language and the Learning of Mathematics in Papua New Guinea", Mathematics Education Centre Report No 16, Papua New Guinea University of Technology, Lae.

Kelly, M. and Philp, H. 1975: "Vernacular Test Instruction in Relation to Cognitive Task Behaviour Among Highland Children of Papua New Guinea", British Journal of Educational Psychology, 42 (2): 189-197.

Lancy, D.F.(Ed) 1978: "The Indigenous Mathematics Project" Papua New Guinea Journal of Education, 14 (Special Issue).

Lancy, D.F. 1979: "Education Research, 1976-1979 Reports and Essays," Department of Education, Port Moresby.

Lean, G. 1976: "Mathematics Learning Project Final Report", Papua New Guinea University of Technology, Lae.

Meek, C. 1978: "Research", A Paper presented at a Seminar on Mathematics Education, Curriculum Unit, Department of Education, Konedobu.

Roberts, A.M. 1977: "Mathematics in Provincial High Schools 1976", Papua New Guinea Journal of Education, 13 (1): 7-15.

Roberts, R.E. and Kada, V. 1979: "The Primary Mathematics Classroom", Papua New Guinea Journal of Education, 15 (Special issue): 174-201.

Roberts, R.E. 1981: "Primary Mathematics Learning", Unpublished M. Ed. thesis, University of Papua New Guinea.

Siford, M. 1981: "A Study of Algebra in the Provincial High Schools Curriculum", University of Papua New Guinea (In press).

Souviney, R. 1980: "The Indigenous Mathematics Project of Papua New Guinea", Indigenous Mathematics Project Working Paper No 5, Department of Education, Port Moresby.

COMPUTER ORIENTED COGNITIVE PROCESS MODELS RELATED TO MATHEMATICAL THINKING

Rod Selden
Papua New Guinea University of Technology

In developing models of cognitive processing the cybernetic or information processing approach has become increasingly popular in recent years. In practical terms this approach involves the development of two related types of models. In one of these human cognitive processing is analysed using the concepts of information processing theory, specifically those concepts which have developed along with the development of information processing machines (computers), and so computer functioning is used as an analogy for cognitive functioning. The second type of model goes one step further and attempts to use the computer to simulate human performance. The field of study encompassing these models has come to be known as cognitive science, and has close connections with related fields such as artificial intelligence.

Ausubel (1968,p122) was extremely critical of this approach. Although he allowed that computer programs do seem capable of performing many of the same kinds of cognitive operations as are performed by humans, such as memorising, generalising, categorising, problem solving and logical decision making, he argued that computers and humans perform these operations by means of different underlying processes. He argued, for example, that the nature of memory storage and retrieval in humans and computers was so different as to be incomparable, and that computers lack many human characteristics, such as the ability to forget, the ability to learn and the ability for imaginative improvisation, creative inspiration and independent thinking.

In fact computers do have remarkably human characteristics, including the three referred to by Ausubel. There aren't many regular computer users who have not had the experience of the loss of an important data file or program due to some bug in the system - computers do forget. Every new program entered into a computer increases its capacity for action and so would have to be described

as a learning event. The addition of a new system program can significantly alter its overall capabilities. In addition to this it is possible to construct learning machines, that is computer programs which make decisions, receive input about the results of those decisions, and use that information to improve future decision making. As regards imaginative improvisation and creative inspiration it is worth mentioning the recent backgammon match between world champion Luigi Villa and a computer program developed by Hans Berliner (Berliner, 1980). The important point is not so much that the computer won (it was very lucky - the world champion actually played better) but that, according to Berliner, the program "shined brightly when it came to exercising imagination. Someone who did not know whether the program was playing white or black might have thought it was the human competitor who was making the sparkling plays and the machine the stodgy ones." In fact it was the other way around. In response to the ultimate question - but can computers really think - the best answer is probably that given by Mauchly, an early computer pioneer, who replied: "I compute so."

Ausubel's more compelling objection is related to the dissimilarity between the processes underlying apparently similar operations in humans and computers, and the question of whether or not this invalidates the models. As computers develop it should be possible to make machines which use processes which are more and more like the processes used by humans. It is highly unlikely that a machine will ever be developed that resembles a human in every aspect of its functioning. Fortunately of course this is not necessary. The value of a model lies not in the extent to which it replicates every aspect of the thing being modelled, but only in the extent to which it adequately represents the particular aspect being studied. We need not be concerned that computers and humans do things in different ways provided this difference is not important in the current investigation. As long as there is something the same about what they do then the model is potentially useful.

A key concept in computing is the program. A program is any well defined prescription for action. It would seem that any intelligently functioning machine has behind its operation some program, some set of procedures for getting information, processing it, making decisions,

operating on its environment and so on. The source of the intelligence that the machine displays is the program. In view of this fact there arises the interesting paradox that, in analysing human behaviour we tend to interpret behaviour which appears to be programed as mindless or unintelligent. Intelligent behaviour seems to be characterised by an absence of programing. A resolution of this paradox is needed if we are properly to use the concept of programing in analysing intelligence.

There is no doubt that humans often perform in a programed manner. The slowness with which people think at the conscious level, together with the necessity for speedy decision making in even the simplest of tasks, indicates that only through programing can people perform at all. This essentiality of programing should warn us against undervaluing its importance, but it does not answer the objection that conscious thought and higher levels of reflective thinking and decision making, that is those characteristics of human mental functioning that we more readily identify with intelligence, appear not to be programed. This appearance is misleading. The flexible, adaptive, creative aspects of higher mental functioning can be explained by, and in my view demand, the existence of powerful, general programs. In this view I would suggest that the source of human intelligence lies in programs, just as it does for machines, and that in analysing intelligence we should be seeking to identify and describe human programs at all levels.

To see why programed behaviour appears unintelligent we need to recognise that programs vary in complexity, generality and a whole variety of other dimensions. Each program would be characterised by an order of intelligence, and for programs of lower order of intelligence the program itself would be more apparent in its behavioural manifestations. Thus it is not that less intelligent behaviour is more programed, but rather that the programs are more easy to see, identify and describe. It needs to be stressed that we are talking in relative terms. Less intelligent behaviour is still intelligent behaviour and the source of the intelligence is the program. The mistake has been to underestimate the potential of programmed activity, thus discounting it as an explanation for more intelligent behaviour.

Skemp (1979a) has built an elaborate theory of intelligence on simple cybernetic concepts. He argues that human behaviour is goal directed and that success in achieving our goals is a major factor of survival. He discusses human mental activity in terms of director systems, namely systems which receive information about the present state of an operand, compare this state with a goal state, and take the operand from its present state to its goal state and keep it there. He hypothesises two such director systems, one whose operands are in the physical environment, which he calls delta-one, and a second system, called delta-two, whose operands are in delta-one. The function of delta-two is to optimise the functioning of delta-one, it is goal directed mental activity. It is impossible to do justice to Skemp's theory here. It's scope is broad, there is no shortage of powerful concepts, and he has been able to apply it to a wide range of psychological areas of concern to teachers. His theory can be seen as an elaboration of the nature and diversity of the programs which govern human mental functioning, and exemplifies the viability of considering programs as the source of intelligence.

As an example of his analysis I wish to mention a recent article (Skemp, 1979b) in which he uses these concepts in his analysis of mathematical understanding. He distinguishes between three types of understanding - instrumental, relational and logical, whose presence is evidenced by respectively the ability to use rules without knowing why they work, the ability to deduce rules from general mathematical relationships, and the ability, with the use of symbolism, to connect mathematical ideas into chains of logical reasoning. He points out that although all learning necessarily involves the delta-two director system, the primary goal of the learning activity may not lie in improving the delta-one system, but in the environment - to be able to give right answers, satisfy the teacher, survive this lesson, or the next test, get through this course and so on. Where these goals dominate the activity is primarily in delta-one, with delta-two being invoked only to get delta-one into passable shape as quickly as possible. The result is instrumental understanding. The problem is that the proper functioning of delta-one requires the construction of comprehensive schemas (knowledge structures), that is relational understanding, but relational learning will only be possible if delta-two activity is dominant. This requires that the external goals of learning be

such as to encourage the setting of appropriate internal goals. In a study of my own (Seiden, 1980) I found that grade 8 students were overwhelmingly uncommitted to achieving understanding, indicating a lack of appropriate internal goals.

Davis and his coworkers have attempted to identify mechanisms involved in mathematical thought (Davis, Jockusch and McKnight (1978), Davis and McKnight (1979), Davis (1980)). Their approach has been to try and catalog behavioural phenomena, mainly in the area of algebraic thinking, and where possible suggest theoretical entities which might lie behind these phenomena. In the 1980 article Davis lists eight such entities, including procedures (programs which govern algorithmic activities), operations on procedures, frames (one of a number of terms used to describe a unit of cognitive structure - an integrated scheme of knowledge), planning language, heuristics, knowledge in other forms, critics and pointers. In programing terms these entities can be considered as referring to the functions of different program types.

Greeno (1978) has attempted to describe understanding of procedural knowledge. He claims that when a person performs a procedure he constructs a representation of the procedure (a program), and the question of understanding is a question about the properties of that representation. He suggests three relevant properties, namely coherence, correspondence and connections to other components of knowledge. In carrying out this process of constructing a representation, or formulating a program, Davis (1980) points out that students have the option of retrieving a program from memory or ad hoc construction right there and then. Both processes are necessary for the efficient use of memory. Being able to construct a representation is important for adaptability, recalling intact programs is important for economy. And there is undoubtedly an interaction between the two - recalled programs are used in the construction process, and the process of construction stimulates recall. Herein lies one of the disadvantages of instrumental learning. Although a student may have a program for carrying out some task, he may be unable to recall it or to make possibly minor adaptions because he lacks the knowledge necessary for the construction process.

Greeno points out that in his work the representations of even relatively simple procedures are very complicated. He suggests seeking simplicity at the level of psychological processes, that is seeking generative principles that produce the complicated structures. In programing terms this might be stated as saying that a useful approach is not to try and unravel the structure of programs in detail, but to try and understand the features of the operation of other programs which are responsible for the creation, restructuring and operation of the programs we wish to analyse. In Skemp's terms we might expect the structure of delta-one programs to be complicated, but the principles by which delta-two programs operate on delta-one programs ought to be simpler.

One particularly promising approach to computer modelling is found in the work of Brown and Burton (1978). By restricting themselves to an analysis of a relatively simple skill (subtraction) they have developed a model that is both compelling and empirically successful. In this model complex procedures (algorithms) are broken down into subprocedures. Each subprocedure consists of a conceptual part representing the intent of the procedure, and an operational part consisting of methods for carrying out that intent. The methods are programs that define how other procedures are combined to satisfy the intent of a particular procedure. Thus each procedure is in one sense self contained, but is related to other subprocedures which may be required to implement that procedure, and perhaps other superprocedures which may call on this procedure. These calling relationships form a network structure, and it is this procedural network which is the basis of the model. Brown and Burton's main purpose in developing the model was to use it as a tool for diagnosing errors, and to do this they made an assumption that a student's procedural network, that is his internalisation of a (complex) skill, could be adequately represented as a variant of a correct version of that skill. The variations were referred to as bugs, and the resulting procedural networks as buggy algorithms. They point out that even for a very simple skill a procedural network can be very complicated, and the number of possible bugs can be quite large. To analyse a test of simple addition and subtraction problems they needed to formulate over 60 different primitive bugs, and many more which were combinations of these. In analysing 20 000 test items returned by 1325 senior elementary students entirely by computer

they found that nearly 40% of the students exhibited consistently buggy behaviour throughout the test.

This success of their model indicates the reasonableness of their assumption that a student's procedural knowledge can be represented by a procedural network which is at most a variant of a correct procedural network, at least in a reasonable proportion of cases and for algorithmic procedures. The main assumptions of the model appear to be that the elements, the nodes of the network, consist of well defined programs which are either present or absent, and that conceptual knowledge only plays a role in organising the procedures in the manner that each program is attached to a concept which represents its intent. One can suggest many inadequacies in these assumptions, both in the direction of more sophisticated knowledge and less sophisticated knowledge. For example Davis (1980) has pointed out that many students can carry out a procedure even though they have no overall organising program - each subprocedure is cued by the result of the previous procedure - so the key program in the network, the one whose intent is the whole reason for carrying out the procedure, may be absent and yet the procedure still work. This can also be true of subprocedures in the network. The model also assumes that the conceptual aspect of the procedure is an all or nothing thing. This is probably the weakest assumption and therefore the one that needs the greatest attention in any attempt to develop the model to describe more sophisticated skills. In spite of all these objections I still find it useful to conceive of the elements of procedures in terms of programs and their intents, and the model, with its simplifying assumptions about these things, provides a useful reference point in thinking about them.

In more recent developments of the above work Brown and VanLehn (1979, 1980) have attempted to develop a generative theory of bugs - that is a set of formal principles which transform a procedural skill into all of its possible buggy variants (that is those which are actually found in students'work). In the earlier work bugs were formulated from an ad hoc investigation of students work, and those bugs identified were tested by seeing how well they predicted errors in other students' work. By trying to develop principles of bug formation they hope to predict errors on new skills without first constructing bugs on an ad hoc basis. This approach is along the

lines of that suggested by Greeno. The resulting theory, which they call repair theory, is fairly technical but some of the general concepts involved in it are worth mentioning. They make the assumption that when a student has unsuccessfully applied a procedure he will attempt a repair, and so they try to explain bugs as patches invented by students to repair a procedure that has encountered an impasse. In order to model the repairing process they develop a generate-and-test problem solver, that is a set of repair heuristics to propose repairs and a set of critics to filter out some of the repairs.

The Brown and VanLehn model is important because it tries to model some of the ways in which children modify their own programs, in terms of mechanisms incorporated in higher order programs. It is unlikely to be completely successful because, in spite of the fact that it involves a number of mechanisms, it only invokes one type of modification process, namely the impasse-repair process. The problem is not that this process doesn't exist, but that other processes may be involved. Consider the following example taken from my study with grade 8 children referred to earlier. I observed the children learn without difficulty the rule for doing the problem $3x + 5x = 8x$. As one means of testing their understanding of this rule I gave them the problem $3x \times 5x$. A common response was either 8x or 15x. This error could be modelled in Brown and VanLehn's terms as a child encountering an impasse (don't know how to do $3x \times 5x$) and repairing it (so I'll use the rule for addition). However most of the children didn't realise that they didn't know how to do the problem - they believed they had already learnt the rule. The impasse-repair analysis is probably less appropriate than an analysis based on the extent to which a procedure can be misconceptualised, with respect to its intent, domain of applicability and so on. This misconceptualisation is probably a consequence of poorly developed concepts of operations, expressions, pronumerals and other elements of the problem. In this case the processes responsible for the construction of a faulty procedure are quite different to those suggested in the impasse-repair model.

Do these approaches suggest ways in which we might model more complex behaviour than the simple procedures mentioned? Given that all knowledge arises out of a construction process, then if one accepts the suggestion of Greeno, and the example of Brown and VanLehn, that

the best way to characterise this knowledge is in terms of the construction processes which generate it, then this sort of model should be possible for quite complex procedures. Given that we can hypothesise processes the test should be not that these processes account for all behaviour, but that they account for some observed behaviour, and that they do not imply behaviour which has not been observed. This allows for other processes to be involved in the construction of similar procedures. The practical difficulties are enormous but there is no theoretical reason why such behaviour could not be simulated on a computer (although simulation is not an essential aspect of the model).

For most of us these possibilities are rather esoteric and of little practical relevance. What then do the approaches mentioned in this paper have to offer us? Whether we like it or not teachers need some ways of thinking about what goes on inside their students heads, in order to interpret their behaviour correctly and in order to provide materials and a learning environment to which the students can respond in a productive manner. Computer concepts provide an important tool of analysis in this regard. They also provide another way of looking at phenomena which are of concern to us as teachers, such as systematic errors, learning without understanding and forgetting.

I would like to go one step further and suggest that some of these concepts may be of value to our students as well. Some understanding of how their minds work may help them become more aware of the nature of their knowledge and may help them develop better learning strategies.

REFERENCES

Ausubel D.P. (1968) Educational Psychology - A Cognitive Viewpoint Holt, Rinehart and Winston.

Berliner H. (1980) 'Computer Backgammon' Scientific American 242 6 54-69

Brown J.S. and Burton R.R. (1978)'Diagnostic Models for Procedural Bugs in Basic Mathematics Skills' Cognitive Science 2 155-192

Brown J.S. and VanLehn K. (1979)'Towards a Generative Theory of Bugs.' Xerox Palo Alto Research Centre Report CIS-2

Brown J.S. and VanLehn K. (1980)'Repair Theory: A Generative Theory of Bugs in Procedural Skills.' Xerox Palo Alto Research Centre Report CIS-4

Davis R., Jockusch E. and McKnight C. (1978) 'Cognitive Processes in Learning Algebra.' The Journal of Children's Mathematical Behaviour 2 1

Davis R. and McKnight C. (1979) 'Modelling the Processes of Mathematical Thinking.' The Journal of Children's Mathematical Behaviour 2 2 91-113

Davis R. (1980) 'Cognitive Models of Algebraic Thought' Paper presented at AERA Conference, Boston Ma, April 1980.

Greeno J. (1978) 'Understanding and Procedural Knowledge in Mathematics Instruction.' Educational Psychologist 12 3 262-283

Skemp R. (1979a) Intelligence, Learning and Action John Wiley and Sons

Skemp R. (1979b) 'Goals of Learning and Qualities of Understanding' Mathematics Teaching 88 44-49

Selden R. (1980)'Conceptualising, Understanding and Performing Mathematical Procedures.' Proceedings of MERGA conference, Vol 2, Hobart, May 1980.

THE USE OF NUMBERICAL FILTERS AS AN AID TO THE SOLUTION OF ALGEBRAIC PROBLEMS:

A PROPOSED PROJECT.

MIKE SIFORD
UNIVERSITY OF PAPUA NEW GUINEA

INTRODUCTION

The following item was part of an algebra test given to 150 U.P.N.G. Preliminary Year students in 1980.

Michael's basic wage is K30 per week.
He is also paid another K2 for each hour of overtime that he works.

(a) *Calculate Michael's total wage for a week in which he worked 4 hours of overtime.*

(b) *If h stands for the number of hourse of overtime that he works, and if W stands for his total wage in kina, write down an equation connecting W and h.*

The responses to part (a) are shown in TABLE 1, below:

TABLE 1: RESPONSES TO PART (a).

RESPONSE	K38	K34	K70	K86	NONE	K68	OTHER	TOTAL
FREQUENCY	116	6	6	6	5	2	9	150

In the majority of cases, sufficient working was shown to indicate how the student had interpreted the problem. For example, K70 was the result of working 4 hours of overtime each day for a 5-day working week; K68 the result a 7-day working week. Neither of the two K68 responses were explained by any working. These could have resulted from the lateral inversion of K86, or more likely, from 2(30 + 4), an extension of the K34 response. When necessary, a structured interview may be used to identify such details.

The purpose of part (a) was to act as a NUMERICAL FILTER which would indicate the way in which each student had comprehended the problem. Responses to part (b) were considered in the light of each student's response to part (a). TABLE 2, below, shows the expected response and the frequency of its occurrance, together with other responses and their frequencies.

TABLE 2: RESPONSES TO PART (b)

RESPONSE TO (a)	K38	K34	K70	K86
EXPECTED RESPONSE TO (b)	$W=30+2h$	$W=30+h$	$W=30+10h$	$W=30+14h$
FREQUENCY	17	0	0	0
OTHER RESPONSES	$W=30+h$ $W=30+4h$	—	$W=30+h$	$W=30+h$
FREQUENCY	6 3	0	1	1

Whilst the numerical problem was correctly interpreted by 116 (77.3%) students, only 17 of these were able to encode the algebraic problem. Some of the reasons for this are listed below.

(1) Part (b) required the formulation of an equation, rather than an algebraic expression similar to the numerical expression of part (a). A better wording is:

Michael's basic wage is K30 per week.
He is also paid another K2 for each hour of overtime that he works.
Calculate Michael's total wage for a week in which he worked.

(a) 4 hours of overtime *(b) h hours of overtime.*

(2) Part (a) was used in an attempt to solve part (b).
In 21 cases (15%) the answer to part (a) was included in part (b).
Some examples of these responses are:

$30w + 4h = 38$

$20h + w = 70$

$w + h = 30 + 8$

$56h + 32w = 88$

(3) There was confusion between the basic wage, K30, and the total wage W kina.

The numerical filter was included for two reasons; firstly to show how the problem was interpreted, and secondly to provide a numerical model on which students could base their algebraic thinking. It is not known how many students attempted some sort of modelling activity, or whether they were successful. A stronger numerical filter may have provided a more substantial model for the algebraic activity. For example,

Michael's basic wage is K30 per week.
He is also paid another K2 for each hour of overtime that he works.
Calculate Michael's total wage for a week in which he worked

(a) 4 hours of overtime

(b) 7 hours of overtime

(c) 12 hours of overtime

(d) h hours of overtime .

may have produced a more successful response to part (d).

THE PROPOSED PROJECT

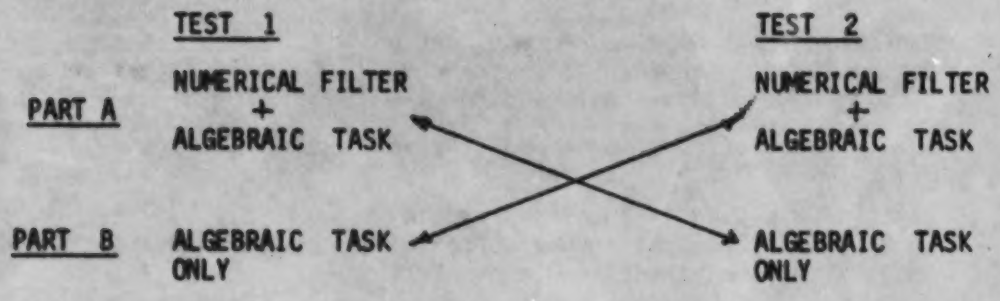
The aim of the project is to investigate the use made of numerical filters in the solution of algebraic problems. The project will be in these stages.

(1) Compile an item bank of numerical-word problems.

(2) Extend each item by adding an algebraic equivalent of the numerical situation.

.../3

(3) Design two tests with the following format. The first part of each test will contain questions consisting of a numerical filter followed by an equivalent algebraic task; the second part will consist of algebraic tasks only. Both tests will contain the same set of algebraic tasks, but numerical filters will be supplied in a complementary manner as shown below.



The ⟷ indicates that the same set of questions is being used. Hence a question in TEST 1 which contains a numerical filter is included in TEST 2 without the filter, and vice-versa. Both tests provide equal opportunities for instant learning.

(4) The tests will be given to U.P.N.G. Preliminary Year students in their normal class groups. Half of each class will take test 1 and the other half test 2. It is expected that the provision of a numerical filter will produce a higher score than on the same item without the filter. Differences in age, sex and ability will be at least partially nullified by the structure of the tests and the random selection of the students.

(5) Preliminary interviews have suggested that students can and do base their algebraic thinking on a numerical model of the situation. It is suggested that the provision of a numerical filter will facilitate this process, but that students may not create a numerical model for themselves when a purely algebraic task is presented to them. Follow-up interviews will be used investigate this situation.

USING THE RESULTS

The purpose of this research is to establish the basis for a teaching strategy for encoding algebraic information. It is suggested that students can be taught to use numerical models for algebraic tasks. If students provide their own models, the strength of the model can be adjusted by individual students according to their needs.

AN INVESTIGATION OF THE MATHEMATICS EDUCATION OF NURSES-IN-TRAINING IN PAPUA NEW GUINEA

AN OUTLINE

PETER SULLIVAN

ABSTRACT

Vocational education in Papua New Guinea is a key element in the Government's programs for development. The many institutions involved in this work aim to train the Grade 10 school leavers to apply their knowledge and skills to the situations which will arise in the pursuit of their chosen vocation. This paper outlines a project which aims to investigate the mathematics education progress of nurses-in-training in Papua New Guinea. Many of the associated issues which have been identified in the course of the investigation are of interest to mathematics educators generally.

1. GENERAL BACKGROUND

There have been reported instances of nurses in Papua New Guinea administering fatally large doses of drugs because of a failure to calculate the correct dosage from the doctor's prescription. These are extreme examples of a situation which had been identified by nursing administrators;that is,the nurses in Papua New Guinea were experiencing real difficulty in applying their mathematical skills at the appropriate time.

Alan Edwards(1979) had been working for some time in the field of post-secondary mathematics, and he identified this problem in these institutions generally, and schools of nursing in particular. He produced a general remedial course aimed at improving the arithmetic skills of the grade 10 school leaver. Evie Wong and Peter Jones(1980) were also working on the problem and ultimately they produced a text book aimed at improving the technical skills of later-year students. There still existed a need for learning materials which would both teach the student nurse to apply her mathematical skills to problem situations and also to provide fundamental instruction in those skill areas which were deficient.

At the request of the Lae School of Nursing, this author undertook to prepare this material. After visits to the hospitals,discussions with a variety of nurse educators, doctors and pharmacists, perusal of examination papers and general assignments, a pilot edition of the "Introduction to Nursing Mathematics" was produced.

The book was distributed to all schools of nursing, the Acting Chief Nurse Educator and the Nursing Council.It is fair to say that the mathematical techniques were sound and the material suitably presented but that the situational analysis was lacking, and the pharmacology was doubtful.The actual drugs were correct but the examples were constructed using any mathematically useful numbers. It seems obvious with hindsight, but the fact that drugs only come in specific quantities was overlooked among other things.This, however,became a positive feature because there were many comprehensive reports on the book,each of which indicated appreciation for the mathematical ideas but varying degrees of dismay at the mistakes with dosages.Paradoxically, had this edition contained less mistakes, the nurses may have been less motivated to send in such detailed information.Each of the schools provided much encouragement as did the Nursing Council and the Acting Chief Nurse Educator. As a result of this, the further situational analysis was made easier, and clearindications were given of

teaching methods which would have the most liklihood of successful implementation.

The initial book was also trialled using a group of nursing aides at Lae School of Nursing.They were predominantly Grade 8 leavers, and so were not really of comparable standard, but many valuable insights into the most appropriate method were gained.An updated trial version was written and printed and copies sent to each school of nursing. As a result 600 were distributed to schools for the commencement of the 1981 year and sufficient orders were later received to justify a reprinting.

As the investigations into the teaching and learning of nursing mathematics developed, it became clear that much more would be necessary than merely the production of instructional materials and the project would have to expand to encompass the many other associated issues.

2. FEATURES OF THE INVESTIGATION

Lack of time and space prohibit a detailed explanation of the associated issues here. They are listed below briefly to acquaint the reader with the extent and nature of the investigation.

2.1 Mathematical Skills of Grade 10 School Leavers

There has been widespread community concern about the standard of the product of the Provincial High Schools.(see for example Harrison,1976, Ros, 1980, Edwards, 1979). The definition of the problem has varied but there is concensus that the students are experiencing very real difficulty in applying their mathematics skills to real situations. There are many contributing factors such as the lack of educational background of community school teachers (Roberts,1979), the difficulties that students experience when learning in a second language (Jones,1981),cultural conflict,the difficult working conditions for teachers in schools, and the rapid localisation of government and industry.(A more detailed discussion of these points is found in Sullivan,1981).

Given the adverse conditions for formal schooling that these students have experienced, it is not surprising to find that the students require further training before they are able to successfully apply their knowledge to the practical situations which arise in the course of their

employment.

2.2 Mathematical Skills in Nursing

The following are classroom examples of the type of problem which a nurse must solve:

a) Prescription: Quinine Dihydrochloride I.M. 10 mg/kg/dose
Available drug: 120 mg in 2ml ampoule
How many ml must be given to a patient of weight 25 kg?

b) Given 100% dettol, make up 2 litres of 2% solution.

c) An I.V. flask must be given over 4 hours. How many drops must run in a minute if there are 15 drops in a ml ?

d) Calculate the estimated date of confinement of a mother the date of the last menstrual period was 25 April 1981. (Gestation is 9 months and 7 days)

These are by no means simple calculations and a nurse must readily perform these calculations with 100% accuracy. There are also many skills which for a variety of reasons seem to present difficulties for P.N.G. students, such as the calculation of times for administering medicines. The job of the nurse is complex and the mathematics involved is difficult and it is necessary that the school leaver be given substantial training to reach the required level of mathematical competence.

2.3 Skill Range

It is not only in mathematics that a nurse must learn difficult skills. In fact even more is expected of a nurse in a developing country than in a developed country. Mooneyhan(1979) points out that the nurse in a developing country must perform the roles of generalised nurse, health educator, labotatory technician, pharmacist, anaethestist, physician, bedside nurse, public health nurse, midwife, psychiatric nurse and more. A nurse in Papua New Guinea can be posted to a Rural Health Centre or clinic where the nurse must deliver a complete range of primary health care without the aid of a doctor. She must diagnose complaints, prescribe and dispense medicines, mend broken limbs, apply sutures, deliver babies, and even keep accounts and stocktake records for the centre. Even in a hospital the nurse sometimes assumes more responsibility than counterparts in Australia in such techniques as lumbar

puncture and removal of excess fluid from body cavities.Considering that students have fewer years of general education(grade 12 is now necessary in Australia), and fewer years of nursing education, the schools of nursing have a difficult job indeed to produce nurses capable of performing the tasks required of them.

2.4 The Schools

There are 18 schools involved in the training of nurses in Papua New Guinea, 7 of which are controlled by the health department, and the rest by mission agencies. There are three distinct programs, General Nurse,Enrolled Hospital Nurse and Enrolled Community Health Nurse. Despite the differences in training any nurse can be required to do any job.It is not clear why there are three courses nor is it clear how the entrants are chosen for each course.The teachers are generally national nurses who have completed further education such as the Diploma of Nurse Education. The competence and experience of the nurse educators is a major issue in itself, but suffice it to say here that whatever the abilities of the teachers in general aspects of nursing, they are somewhat less confident at teaching the mathematics aspects of the course. Since there is a shortage of trained teaching staff it may seem unwise to support so many schools, many of which are very small. One of the reasons is that nurses-in-training actually staff the hospitals for approximately 50% of their three year course;in fact ,they are needed to help keep the hospitals running. This of course has many real advantages since practical on the job training is arguably the best way to train nurses, but it places an extra constraint on the courses since the students must be quickly prepared for the demands of hospital work.

3. EDUCATIONAL ISSUES

There are number of educational issues which relate to nursing mathematics.

Arithmetic skills.

Time

Ratio

Scales

Instructional methods

Validation of performance

4. STRUCTURAL CONSTRAINTS

The following is a list of the factors which cannot be significantly changed in the short term, but which must be considered.

Historical perspective and rate of localisation

Course differences

Allocated teaching time

Qualifications and experience of teachers

Clinical supervision

5. ATTITUDES

Professional attitudes, motivation and the individual's perspective of the education process are important considerations. The following have been isolated as key elements in the teaching and learning process.

Professional attitudes and the qualities of nurses.

The community status of nursing.

The career motivation of teachers.

The confidence of the teachers.

The attitudes of teachers and students to mathematics.

Professional motivation of staff nurses.

6. THE PRODUCTION OF TEACHING AND LEARNING MATERIALS

One of the major aspects of this project is the production of teaching and learning materials. This involves the following.

Preliminary data collection and situational analysis

Production ,dissemenation and feedback

Teacher support and in-service training

Evaluation of the use of the materials

Evaluation of the content

Reconstruction

7.CONCLUSION

There are many and varied issues associated with this investigation. In a sense, the project is a case study for courses in vocational mathematics, and may well have implications for a theory of curriculum development in non-school environments.

REFERENCES

EDWARDS, A. 'Prelininary Report on the Basic Arithmetic Test Carried out in Post-Secondary Institutions in P.N.G. in 1979'. Mathematics Education Centre Report No. 6, Papua New Guinea University of Technology, 1979.

HARRISON, B.N. 'Naught for our Comfort', Maths News, 1:18 - 26, 1976.

JONES, P. 'Mathematical Language and the Learning of Mathematics in Papua New Guinea'. Mathematics Education Centre Report 16, Papua New Guinea University of Technology, 1981.

MOONEYMAN 'The Professional Nurse in Developing Countries. Practice and Preparations'. International Nursing Review, Jan/Feb 26 (1), 17-20, 1979.

ROBERTS, R.E. and KADA, V ' The Primary Mathematics Classroom'. Papua New Guinea Journal of Education 15, 174-201, 1979.

ROS, L 'Transition Rates in Developing Countries, Mimeographed Paper, Goroka Teachers College, November, 1980.

SULLIVAN, P 'The Standards Debate: An Altematic Strategy'. Mathematics Education Centre Report No. 15., Papua New Guinea University of Technology, 1979

WONG E. and JONES P. 'Phamacology and Drug Dosage Calculations'. Mathematics Education Centre Press, Lae, 1980

A PROPOSED CATEGORIZATION SYSTEM FOR STUDENTS ERRORS IN MATHEMATICS.

W.F. TOVIRIKA, H. KORIM AND L.S. DUBÉ

PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

INTRODUCTION

The entering student at the Papua New Guinea University of Technology has undergone 10 years of formal mathematics teaching. What specific mathematical knowledge have actually been learned? This paper discusses what happened during a study which attempted to determine the presence (or absence), the correctness (or incorrectness) of those "learning products of teaching".

Because the presence and correctness of a person's mathematical knowledge (or any other kind of knowledge) cannot reliably be detected by mere pencil and paper tests, the researchers used structured individual interviews for an in-depth analysis of the students' learnings. These interviews focused on the sources of the errors made by the students in a pencil and paper test. A search model to determine the sources of errors was used in the interviews. The lessons learned from the conduct of these interviews are also discussed in this paper.

THE PENCIL AND PAPER TEST

At the beginning of the 1980 school year a test was administered to the entering students to determine what mathematical knowledge they had learned in the high

school. The test had 2 parts. The first part (called the A test) consisted of 50 computation questions which involved simple and routine additions, subtractions, multiplications and divisions of natural numbers, integers, fractions and decimals. The second part (or the D test) consisted of 50 questions which require recall, selection, and application of one or more mathematical concepts, principles, processes, and algorithms within the set of real numbers.

To illustrate:

One question in the A test was simply written thus:

$$95\overline{)67355}$$

From the D test a question was:

$\frac{1}{R} = \frac{1}{3} + \frac{1}{6}$. What is the value of R?

The study analyzed the errors made by a sample of students who took this test.

THE SAMPLE

101 entering first year students took the test which was administered on the first class meeting of the year. Their test papers were marked and scored. From an alphabetical listing of the examinees' names and with the aid of a set of random numbers, 31 names were drawn from this list. These 31 students comprised the sample for the study.

The sources of the errors made by each student in the sample were brought out and categorized using structured individual interviews using a search model developed

by Newman as reported by M.A. Clements' in his article "Analyzing Childrens' Errors in Written Mathematical Tasks". All interviews were audiotaped. The student behaviours observed during the interviews together with the recorded student-interviewer talk provided the data from which the researchers drew their recommendations and conclusions of this study.

THE SEARCH MODEL

According to Clements, Newman defined a 5-level hierarchy of the causes of errors in the course of obtaining a correct solution to a one-step problem. The 5 levels are:

1. Errors in reading the problem.
2. Errors in the comprehension of what is read.
3. Errors in the transformation to a mathematical model.
4. Errors in the application of the necessary process skills.
5. Errors in the encoding of the answer obtained.

In addtion, at each level, (but distinct from it) may occur errors which are due to carelessness and motivation. Newman also took into account errors which are due not to the problem confrontee, but to the poser of the problem. This source of error she categorized as "question form" and is disjoint from the 5-level hierarchy and from carelessness and motivation.

All the interviews conducted in the course of the study systematically asked the student the structured set of questions which correspond to each level in the Newman hierarchy. The questions are as follows:

1. Please read the question to me.
2. Tell me what the question is asking you to do.
3. Tell me how you are going to find the answer.
4. Show me what to do to get the answer.
5. Now, write down the answer to the question.

THE INTERVIEWS

Only the student and the interviewer were present during the interview which was conducted in a room in the library. To establish rapport with the student, the interviewer started by asking the student to solve 2 questions which he got right in the test. For example, a subject answered the following questions correctly:

$5\frac{1}{4} - 2\frac{3}{4} = ...$

Find a number bigger than 1 but smaller than 1.1.

When the student gained confidence and can speak his thoughts freely, than the interviewer went ahead with the study. He asked the subject to work out the problems for which he got wrong answers in the test. These problems were presented in a non-test format having been pulled out and recopied from the student's test papers.

The student worked out the answers one at a time. If he got a correct answer the interviewer noted this down and asked the student to go to the next problem. If the student got a wrong answer the interviewer determined the sources of error from the students' responses to the 5 questions of the Newman hierarchy.

The following is a transcript from an interview where the student had just written down a wrong answer to the question: $\sqrt{64 + 36}$.

I: Read the question to me.

S: Square root of sixty four plus thirty six.

I: Tell me what the question is asking you to do.

S: I must add the square root of sixty four and thirty six.

I: Tell me how you are going to find the answer.

S: Find square root of 64 and 36 then add.

I: Now show me how you got the answer.

(The student wrote down:

$\sqrt{64 + 36} = 8 + 6 = 14$)

I: So what is the answer to the question.

S: Fourteen.

Because of the large size of the sample and time table considerations, it was not possible to finish all the interviews within the first week of classes as was the plan of the researchers. The best that could be done was to finish all the interviews by the end of the first quarter (or the first eight weeks) of classes.

THE RESULTS OF THE INTERVIEWS

A. Errors Due to Question Form.

The 31 students in the samples made errors in 32 test questions. In 21 of these questions, they were directly asked to perform additions, subtractions, multiplications and divisions where the operation was stated in symbols like,

$$5\frac{1}{4} - 2\frac{3}{4}.$$

In the other 11 which were stated in words, the question was direct and straight forward like,

> 2 kg of meat cost K5. What is the cost of 5 kg?

Thus, with one possible exeeption which was missed by 8 students in the sample it can be concluded that none of the errors made by the sample could possibly be due to question form. The one exception was the question:

> David and Peter have to share 4.00 shillings in the ratio 3:5. Peter gets _____. David gets _____.

This question might have been incorrectly answered because of the unfamiliar word "shillings".

B. Errors Due to Carelessness and/or Lack of Motivation

A closer look at the Newman categorization of the sources of students' errors in one step problems

reveals that these sources can be partitioned into two disjoint subsets. The elements of the first subset i.e., "question form" are conditions external to the student have been discussed earlier in this paper. The second (and major) subset consists of conditions within the student which may be classified as affective and cognitive sources. The cognitive sources are specified in the 5-level hierarchy (reading, comprehension, transformation, process skills and encoding). Lack of motivation and/or carelessness which may occur during any of the 5 levels of the hierarchy are the affective sources.

During the interview, whenever a student in the sample correctly solved a question which he had missed in the test, the interviewer concluded that the earlier error was due to carelessness and/or lack of motivation. Of the 221 errors committed by the sample, 130 or 58% were due to carelessness and/or lack of motivation. 92 out of the 130 errors were done on the 21 direct symbolic questions, 38 were committed on the 11 worded questions.

C. The Errors due to Cognitive Sources Within the Student. Table 1 below shows the distribution of the 91 errors committed by the sample among the 5 levels of the Newman hierarchy.

Table 1. Number of Errors Which Were Committed by the Sample Due to Each Level of the Newman Hierarchy.

Sources of Error / Question Type	Reading	Comprehension	Transformation	Process Skills	Encoding
Direct, Symbolic Questions	0	2	17	40	3
Worded Questions	0	5	12	6	6
Totals	0	7	29	46	9

1. Reading.

Because of the simplistic and directly worded questions in the test the lack of errors due to reading was expected.

2. Comprehension.

Of the 7 errors due to comprehension, 2 were made on direct symbolic questions, 5 were committed in the worded questions. Below are portions of tapescripts illustrating the comprehension errors.

Example 1. A comprehension error made on the direct symbolic question: $\sqrt{46 + 36}$

I: Read the question to me.

S: Square root of sixty four plus thirty six.

I: Tell me what the question is asking you to do.

S: I must add the square root of sixty four and thirty six.

This was classified as a comprehension error because

although the subject's reading of the symbols was apparently correct, when he worked out the problem, he wrote down:

$$\sqrt{64 + 36} = 8 + 16 = 14.$$

which was a symbolic representation of his statement in response to the question: Tell me what the question is asking you to do.

Example 2. A comprehsion error made on the worded question: $\frac{1}{R} = \frac{1}{3} + \frac{1}{6}$. What is the value of R?

I: Read the question to me.

S: One R equals one third plus one six.
What is the value of R?

I: Tell me what the question is asking you to do.

S: To find the value of one R.

Here again the subject's working out and answer showed that he did not comprehend the question, though his reading of it was correct. What he did was:

$$\frac{1}{3} + \frac{1}{6} = \frac{2 + 1}{6} = \frac{3}{6}$$

And he concluded that $R = \frac{1}{2}$, showing that he did not understand the distinction between $\frac{1}{R}$ and 1R.

3. Transformation.

In the Newman hierarchy an error is due to transformation when the subject cannot "carry out the transformation from the words to the selection of the appropriate mathematical model." The following are examples of errors

due to transformation.

Example 1. The question was: Find a number between 2.04 and 2.05.

After the subject had just responded correctly to the questions: "Read the question to me" and "Tell me what the question is asking you to do".

I: Tell me how you are going to do the question.
S: Divide 2.05 by 2 to get the number between .05 and .04.

Example 2. The question was: 0.6666 ..... + $\frac{1}{3}$.

I: Read the question to me.
S: 0.6666.... plus one third
I: Tell me what the question is asking you to do.
S: Add these two numbers.
I: Tell me how you are going to do the question.
S: Add straight.

Here again, it was only after the subject worked out the solution that the error was categorized as due to transformation. The subject's working out was:

$$0.666.... + \frac{1}{3} = 0.6 + \frac{1}{3} = .6\frac{1}{3}.$$

4. Process Skills. 116

46 of the 91 errors or 50% due to cognitive sources were caused by the sample not being able to apply the

operations which he had indicated he would do to get the answer to the question.

In this example, the subject was carrying out the solution to the question: $5\frac{1}{4} - 2\frac{3}{4}$.

The subject had just stated that to do the question he was going to "change to improper fraction then subtract them."

I: Now get the answer to the question.

Subject wrote:

$$\frac{21}{4} - \frac{11}{4} = 10$$

I: What is your answer to the question?
(He was checking if the subject was just forgetting to copy the common denominator).

S: The answer is 10.

4. Encoding.

An error due to the inability to present the answer in an acceptable written form was classified by Newman as an encoding error.

For example: The problem was: David and Peter have to divide 4.80 shillings between them in the ratio 3:5. Peter gets _____. David gets _____.

The subject's working out was:

$$\begin{array}{r} 60 \\ 8\overline{)480} \\ 48 \end{array} \qquad \begin{array}{r} .60 \\ \times 3 \\ \hline 1.80 \end{array} \qquad \begin{array}{r} .60 \\ \times\ 5 \\ \hline 3.00 \end{array}$$

Then he filled the blanks in the problem as follows:

Peter gets 3.00 David gets 1.80.

LESSONS LEARNED FROM THE STUDY

1. What is a One-Step Problem

The search model as evolved by Newman applied to one-step problems. The "problems" on which the sample used in this study made errors, the sources of such errors being in turn educed by using the search model were simplistic questions like:

$-16 - 6\frac{2}{3}$

Find a number between 2.04 and 2.05.

These questions were classified by the researchers as one-step problems.

But do such questions really ask the solver to perform a one-step procedure? Consider the very simple question stated in symbols thus,

45689 + 49

To answer it one has to arrange the numbers in coloumn making sure the decimal points, units, tens, etc. are aligned (mentally if not writing explicitly), add using stored arithmetic facts, "carry", (or rename numerals such as 18 as 10 + 8, etc.)

This was discovered in the course of the interviews when the students in the sample answered the third and fourth questions designed to bring out errors in

transformation and in process skills. Here, the researchers realized that:

1. what they classified as a one-step problem was really multi-step, and more important,

2. the sources of most errors were due to errors in carrying out sub-procedures in the attempt to get the answer to the question.

Hence, a most useful outcome of the study was the realization of the need to sub-categorize the sources of errors due to errors in process skills if the search model was to be a really useful diagnostic and etiologic instrument for error analysis.

2. Reading and Comprehension Errors.

When the questions to bring out reading and comprehension errors were used during the interviews, the sample whose maturity level (and probably reading level) were higher than that of Newman's,

1. all read the questions correctly, and,
2. most merely repeated the question when they were asked: "Tell me what the question is asking you to do."

Could this be due to the fact that the problems used in this study were either stated in symbols, or if stated in words, words which were straight forward?

3. Mutually Exclusive and All Inclusive Categorization Systems.

A most important property of a category system is that its elements should be mutually exclusive and all-inclusive. That, for this particular sample, the first of these criteria was not satisfied was discovered when questions 3, 4 and 5 were all answered when question 3 was asked. Following is a transcript which illustrates this:

Example 1. The problem was 2.16 ÷ 3

I: Read the question to me.

S: 2.16 divided by 3.

I: Tell me what the question is asking you to do.

S: To divide 2.16 by 3

I: Tell me how you are going to do the question.

(The student did not answer. He wrote:

$$\begin{array}{r} 0.72 \\ 3\overline{)2.16} \\ \underline{21\ x} \\ 6 \\ \underline{6} \\ 0 \end{array}$$

which represented his answer to questions 3, 4 and 5).

Example 2: The problem was: Find a number between 2.04 and 2.05

I: Read the question to me.

S: Find a number between 2.04 and 2.05

I: Tell me what the question is asking you to do.

S: Find a number between 2.04 and 2.05.

I: Tell me how you are going to do the question.

S: Use number line to get 2.045

I: Now get the answer to the question

(The student wrote down what he said in response to the last question thus,

A PROPOSED CATEGORIZATION SYSTEM OF THE SOURCES OF COGNITIVE MATHEMATICAL EPRORS.

Is it possible to evolve a categorization system whose elements are mutually-exclusive and all inclusive and which will determine the students' cognitive errors in the solution of n-step ($n \geq 1$) mathematical problems? The researchers plan to try out a variant of Newman's system during the 1981 school year, on students making errors not only in problems testing basic arithmetical skills but in problems in university mathematics.

The system follows:

Source of Error.

1. Reading
2. Comprehension

} This may not be present when the problems are stated in symbols like $\int x^2 dx$. These categories are only meaningful when the students have encountered or "learned" these

symbols. Also, when the problems are stated in symbols, there is a possibility, as shown in this study, that these two categories will not be mutually exclusive.

3. Transformation/Process Skills/Encoding.

3(a) Algorithm. This may be educed by the question: What rule (formula, algorithms, principle, etc.) are you going to use to get the answer? Examples of probable student response are "multiply numerator and denominator" "invert division and multiply" "use the chain rule."

3(b) Notation. This includes carrying, borrowing, changing to improper fraction, moving the decimal point, changing percent to decimal, changing ratio to fraction, changing the index to a negative number, etc. This may be educed by the question: What change in the symbols are you going to do in order to use this rule?

3(c) Storage (of basic facts). Some examples are $2 \times 3 = 6$, $0 \div 10 = 0$, etc. This is easily discovered from the students working out, and also by interviewer questioning. Here, the interview

could be less structured and approach the Piagetian clinical method to get more information.

3(d) Encolding. May be educed by the question: What is your answer to the problem?

AFFECTIVE AND COGNITIVE SOURCES OF ERRORS.

Out of 221 errors committed by the sample, 130 were due to carelessness or lack of motivation. This high percentage of errors due to affective sources has implications for the teacher. This is because an error due to carelessness is listed only when the student missed the problem in the test, missed it when the interviewer asks him to do the problem again, but gets it correct when he works out the problem in stages as he responds to the interviewer's five questions. Could it be possible that the five questions are guiding him to the correct solution? A teaching experiment to determine if the use of these 5 questions (or any other set of questions) results in more efficient problem solvers might be worthwhile.

REFERENCES

CLEMENTS, M.A. 'Analyzing children's Errors on Written Mathematical Tasks', EDUCATION STUDIES IN MATHEMATICS 11: 1-21, 1980.

THE PERFORMANCE OF NATIONAL HIGH SCHOOL STUDENTS AT UNIVERSITY

C.W. Wilkins

In 1980 the intake of first year Engineering at the University of Technology included both ex-preliminary year and National High School students. The performances of these two groups of students are compared and the possible causes for the improved mathematics performance of the latter surveyed. The results have suggested a three year longitudinal study of mathematics achievement variables at National High and University.

In 1980 students with various educational backgrounds were accepted into the first (foundation) year Engineering course at the University of Technology. Jones and Wilkins (1981) have compared, with reference to this course, the early performance of students who graduated from National High School against the performance of overseas students, mature age students, and students who progressed through a University preliminary year. The aim of the comparison was to guage the relative preparedness of students who undertake tertiary level mathematics programs. The present paper updates the performances of National High School graduates and students from the University preliminary

year. The results indicate that ex-National High students outperform ex-preliminary year students at University Mathematics.

One reason for this improved performance may be that the mathematics processing skills of students are maturing at National High. This has suggested a longitudinal study in which the mathematics development of students will be monitored through the National High School system and into University.

Comparative Student Performance

At the University of Technology only Engineering and Business Studies courses have sufficient student numbers to enable a realistic statistical survey of student performance. In terms of mathematics programs the more interesting of these two courses is Engineering. Here students take 11 hours of Mathematics Methods/Engineering Mathematics in their first year, and, depending on the Engineering option they select, may be required to take Mathematics courses through to their fourth year of studies. The majority of this mathematics is calculus based. In contrast Business Studies requires minimal mathematics, and with few exceptions the students are required to apply familiar concepts of algebra to financial problems, and are introduced to basic descriptive statistics. From 1980 both Engineering and Business Studies have accepted only National High School graduates into their programs of study, and so 1980 gives the final opportunity to make a direct comparison of ex-National High and ex-preliminary year students.

Table 1 summarizes the end-of-year marks attained by students in the Mathematics/Science/Language subjects in Foundation Year Engineering. It is evident from this table that while there is a comparable performance in the subjects Engineering Mathematics, Language, Chemistry and Physics, the National High graduates are clearly outperforming the ex-preliminary year students in Mathematics Methods.

TABLE 1

Mean scores - with standard deviations in brackets - for the end-of-year subject results for ex-National High and ex-preliminary year Foundation Year Engineering students.

Subject	Ex-National High	Ex-Preliminary Year
Mathematics Methods	64.0 (11.1)	55.1 (12.0) †
Engineering Mathematics	69.3 (12.0)	64.4 (11.0)
Physics	53.7 (11.3)	51.9 (10.4)
Chemistry	66.7 (6.9)	66.5 (13.9)
Language	58.6 (7.3)	56.6 (7.6)
	(50 students)	(27 students)

† difference significant at 0.01 level

It should be noted that the syllabii for Mathematics Methods and Engineering Mathematics do not favour the National High students per se. In Mathematics Methods the syllabus is calculus based - with emphasis placed on differentiation and integration. The material is new to both groups of students. In Engineering Mathematics the syllabus requires that mathematics be applied to engineering problems, and it is generally the engineering concepts (e.g. mechanics) that the students find more difficult.

Given the extra year of general schooling of the National High students the similarity of results in subjects other than Mathematics Methods is surprising. However of more interest at present is their performance in Mathematics Methods. Although these students would appear to have no direct advantage in the course through familiarity with the subject material, it would appear that the extra year of pre-calculus mathematics enables National High students to better assimilate new mathematics ideas as they are introduced.

TABLE 2

Summary of Foundation Year Engineering end-of-year grades for Mathematics Methods.

Grade	Ex-National High	Ex-Preliminary Year
A	1	-
B	3	1
C	21	6
D	22	15
F (Fail)	7	9
Discontinued mid year	2	3

Final 1980 grades for Mathematics Methods are recorded in Table 2, and the grades emphasize that in general the performance of National High graduates is more satisfactory than that of the ex-preliminary year students.

Table 3 indicates a similar trend in performances for students enrolled in Business Studies. As indicated earlier the Mathematics syllabus is not as extensive as the corresponding Engineering syllabus, which perhaps explains the improved relative performance of the ex-preliminary year students in Mathematics. Statistically the difference in performance between the two groups for this subject is marginally significant, and again the superior performance of the National High students evident in Mathematics is not observed in Language results (or in other professional subject results not reported here - see Wilson, 1981).

The Engineering and Business Studies results summarized above suggest that National High graduates are better equipped to master the concepts of University Mathematics than are

TABLE 3

Mean scores - with standard deviations in brackets - for semester 1 subject results for ex-National High and ex-preliminary year Business Studies students (adapted from Wilson, 1981).

Subject	Ex-National High	Ex-Preliminary Year	
Mathematics	69.3 (11.4)	63.0 (16.4)	*
Language	60.5 (7.7)	59.0 (6.8)	
	(59 students)	(27 students)	

* difference significant at 0.05 level

the ex preliminary year students - particularly when the concepts are more advanced.

A Proposed Longitudinal Study

Why the singular improvement of mathematics performance of the National High graduates? Performance in other subjects suggests that neither maturity or the possibility that the National High students are (by selection) the better students could account for the improved mathematics performance. It is possible that a greater familiarity with pre-calculus concepts assists in the assimilation of new procedures, but the answer may lie in the results of a 1980 study in which Lean and Clements examined the mathematics abilities of Foundation Year Engineering students. In this study six mathematics variables - spatial ability, knowledge of spatial conventions, analytic-visual processing preferences, Gestalt imagery, non-verbal intelligence and elementary mathematics skills - were evaluated. The effectiveness of using these variables to predict mathematics performance was guaged by correlating results with quarter year test scores in Mathematics Methods and Engineering Mathematics.

TABLE 4

Coefficients for correlations between mathematics variables and mathematics test scores for Foundation Year Engineering students (from Lean and Clements, 1980).

	Spatial Ability	Knowledge of Spatial Conventions	Non-verbal Intelligence	Analytic-Visual Processing
Mathematics Methods	0.35	0.28	0.21	0.31
Engineering Mathematics	0.31	0.20	0.30	0.24

The two variables Gestalt imagery and elementary mathematics did not appear related to performance in either mathematics subject. The remaining four variables correlated significantly with test results, and the coefficients are reproduced in Table 4. A multiple regression indicated that the analytic-visual processing variable was the best single predictor of mathematics performance, contributing 50% more to the Mathematics Methods score than the next best predictor - spatial ability.

Further to these results Table 5 gives a breakdown of these four variable scores by student background. On examining this table and the conclusions of the Lean/Clements report it is tempting to speculate that a preference for analytic processing over visual processing (indicated by a lower process score) may be the largest single factor that allows National High graduates to better grasp new mathematics concepts at University.

These results have suggested a longitudinal study in which a group of National High School students will be monitored as they progress through grades 11 and 12 and into University. The primary aim of the study will be to isolate any changes

TABLE 5

Mean scores - with standard deviations in brackets - for the mathematics variables for ex-National High and ex-preliminary Foundation Year Engineering students (from Jones and Wilkins, 1981).

Variable	Ex-National High	Ex-Preliminary Year
Spatial Ability	67.6 (15.8)	63.2 (16.2)
Spatial Conventions	31.1 (5.4)	30.8 (4.5)
Non-verbal Intelligence	8.3 (2.2)	7.7 (2.9)
Analytic-Visual Processing	-4.6 (7.3)	1.2 (7.0) +
	(61 students)	(32 students)

+ difference significant at 0.01 level

that may occur to analytic-visual processing preferences (or abilities) or any other mathematics achievement variable included in the study, and to guage the importance of these variables in predicting mathematics performance.

The duration of the study will be three years, and the study will be a joint MEC/University Mathematics Department project.[1] A data bank will be generated for each student - this will consist of demographic information, records of mathematics performance, and ratings on selected mathematics variables. In addition to the analytic-visual processing variable this third section of the data bank will include measures of student's memory spaces and levels of cognitive development attained over the duration of the study. Other variables, including spatial ability and language-mathematics interactions will be incorporated into the study, although possibly as static variables.

At the conclusion of the study we would hope to better understand the mathematics abilities, strengths and weaknesses of the students who enter the tertiary system,

and that this will in turn give direction for developing, and hopefully upgrading, the present mathematics syllabii. With a broadening of the National High School base there is a belief within the Mathematics Department, backed up by evidence presented in this paper, that the students at the University of Technology will be better equipped to succeed in Mathematics and will attain the general level of expertise required of our graduates.

Note: 1. Participating in the study will be P. Clarkson of the Mathematics Education Centre, and P. Jones, H. Whippy and C. Wilkins of the Mathematics Department, University of Technology.

REFERENCES

Jones P.L. and Wilkins C.W. (1981) 'Mathematics Achievement at Tertiary Level - A Comparative Study at the Papua New Guinea University of Technology' PNG Journal of Education (in press).

Lean G.A. and Clements M.A. (1980) 'Spatial Ability, Visual Imagery and Mathematics Performance' MEC Report 12 Mathematics Education Centre, University of Technology, Lae, Papua New Guinea.

Wilson R. (1981) 'First Year Accountancy and Business Studies Students 1980' Internal University of Technology working paper.

LANGUAGE AND MATHEMATICS EDUCATION: AN INTERNATIONAL PERSPECTIVE

BRYAN WILSON

THE BRITISH COUNCIL, LONDON

For many years, we have been aware in a general way that language issues are important in mathematics education. The immense amount of work that has been done here at Lae on collecting PNG number-system words is indicative of such awareness.

Recently this awareness has become more clearly focussed, and it has also deepened into concern. Many of the problems that we have thought of in a somewhat vague way as 'cognitive' are being seen to be linguistic in origin. The interactions between language and mathematics education are being analysed, and a variety of research studies undertaken on specific aspects of this interaction. A growing literature is becoming available.

I wish to distinguish between two fundamentally different situations. One is where there is a relatively uniform language environment, and education takes place in the child's only, or first, language. Such a situation is not free from language - in-maths-education problems; see, for example, Austin and Howson, where about 90% of their 600+ references concern a monochrome language environment. In most countries, however, we are concerned with the other situation, that of a multi-language environment, in which vast numbers of children learn mathematics though a language other than their mother tongue. PNG is, of course, the most extreme example of such linguistic complexity of any country in the world. In the presence of this audience it is superfluous to emphasise that, and would be presumptous to talk about any particular aspect of it further. Rather I wish to give you a few glimpses of what is being done elsewhere in the world.

Some of this experience may be of some relevance to PNG, but it must be borne in mind that the technical issues that we face differ from one language environment to another.

Our problems also depend on the particular policy for language in education that a country decides. As teachers we have to work out the educational implications of language policies that are decided by other people. The language policy in the education system of almost any country is not decided on educational grounds. It is decided on other grounds altogether, sociological grounds, political grounds, economic grounds, in terms of employment; very rarely is it decided on strictly educational criteria. The policies are made outside the world of education. We as educators have to take the policy that we're landed with, and work out the detailed implications of it as far as our profession is concerned. And that is true in most countries of the world. These language policies differ enormously, even among, say, the English-speaking countries of Africa. Many of the Anglophone countries of Africa have a policy in education whereby you have a mother-tongue as the medium for Primary 1, 2, 3 and 4 and then a switch to English. Many of the countries of Southern, Central and East Africa are like that. But there are some countries which have a different policy, for example, Zambia. In Zambia they teach in English throughout from the beginning of Primary 1. A child goes to school, at age 5 if it's fortunate, to its Primary 1 class and from the very first morning it is taught in a language which it knows nothing about. It has probably never heard English spoken, or certainly it has never understood anything of English, and yet it is taught entirely in English for Primary 1. And there are reasons for this in terms of the complexity of the language situation in Zambia, with 73 languages spoken in the country, 72 of them being Zambian languages, African languages, and 1 being English. In Tanzania they adopt the opposite policy. This is very interesting, because one thinks of Zambia and Tanzania in many ways as very closely related, in their political philosophy and so on, the friendship of their Presidents,

and yet they adopt quite opposite language policies. Tanzania is steadily replacing English as the language of education by Kiswahili. The process has already gone right through primary school. There's a little hiatus while they prepare enough materials and then it will be introduced throughout secondary schools. Ultimately the intention is that university education should be entirely in Kiswahili.

You get a similar variety of policy in Francophone African countries. Morocco, for example, teaches in Arabic in the first two primary years. In primary 3 and 4 some subjects continue to be taught in Arabic, others start being taught in French. In Primary 5 a few more subjects are taught in French, but a few still are taught in Arabic. Mathematics, incidentally, changes from Arabic to French between Primary 4 and Primary 5. It's not one of the first subjects to be taught in French, it's in the second wave. Algeria: Primary 1 and 2 in Arabic, and then from Primary 3 onwards some subjects continue in Arabic, and others are taught in French. The position of the mathematics course is interesting. From Primary 3 onwards they assess children according to ability, and the top two-thirds are taught mathematics in French and the weakest one-third are taught mathematics in Arabic. I've no idea what the implications of that are, but I think it's a fascinating fact.

Other countries, such as Senegal, teach in French throughout. There are other countries such as Guinea which are steadily getting rid of French as the language of education, and replacing it by one of their 8 national African languages. I could go on - but that's enough to give you an indication that different countries have completely different policies. And those policies, as I say, are not usually decided by educators, they are usually decided by politicians.

Outside Africa, India. India has a highly complicated language situation. It's one of these countries which you cannot generalise about, because anything that is true in India, you can guarantee the opposite is probably also true. But mostly

children in India have to learn three languages at school, one being Hindi, one being English and one being another Indian language, which for the lucky ones would be their mother-tongue. They might be educated through the medium of any one of those three languages as the medium but they would have to learn the other two as subjects. And you get all permutations of that.

Malaysia is a country which is getting rid of English as the medium of education and replacing it entirely by the national language, Bahasa Malay. Incidentally, when the policy was decided only a minority of the population of Malaysia could actually speak Bahasa Malay. The reason for the language policy is overtly political, openly political, and the educationalists are left struggling with the implications of that. These are particularly acute in science and mathematics.

There is a similar situation in Indonesia, where the medium of education is Bahasa Indonesia, very similar to Bahasa Malay. It happens to be the mother-tongue to a tiny minority of the population of Indonesia. Indonesia is a country of 125 million people. One of the tiny islands comprising this vast country has as its mother-tongue the language which was adopted as the national language and now is learnt and spoken and used by everybody, and used throughout education.

There are other countries, as well as those one or two French-speaking African countries I've mentioned, where different subjects are taught in different languages. As example is the Philippines, where mathematics and science are taught in English, and also English of course is taught in English. All the other subjects are taught in Pilipino, the national language. It is very interesting why they choose this way. Educationally, there are very strong reasons for teaching mathematics, at least in primary schools, in the national language. This is true particularly in the Philippines, because the structure of the language is such

that numbers are easier in Pilipino than they are in English for young children. But they throw that advantage away and adopt this policy.

Singapore similarly has a policy where, in many of the schools, different subjects are taught in different languages. Generally speaking the pattern is science and mathematics in English, and some or all the other subjects in one of the other languages, probably the child's mother-tongue.

An interesting, and sad, example of political motivation of language policy is found in South Africa. Some years ago they launched a programme to develop - I think that was the word they used - to develop the language of Northern Sotho. They took the numeral words, the words for all the counting numbers, and by decree simplified them. A number like 3 million, 3 hundred thousand, 3 hundred, takes two and a half lines to write out in the traditional orthography, the traditional language, and only a line and a half after the White South Aricans had been at work on it. And a reason for doing this is because you can then make a slightly stronger case for using Northern Sotho as the language of education, for forcing it through as the medium of education. And that policy was seen to be an important plank in the platform of separate development, of apartheid.

My point is that the motivation for this sort of thing is entirely political; it's not educational. These other reasons, these non-educational reasons, are perfectly good reasons, they're very valid reasons, and very deep-rooted.

It's interesting to compare this also with what happened in the past. Let me remind you, or maybe tell you, what happened in my own country some hundreds of years ago. At school level until the middle of the 16th century all textbooks in England were written in Latin. The school at which I last taught was in fact already about three hundred years old at that time, and all the textbooks it used were in Latin. All mathematics

was written in Latin, which was of course the former Colonial language. It had the advantage of being a world language, but it had the disadvantage of being the language of the educated. Various people suggested in the 16th century in England that perhaps there was something to be said for textbooks being written in English. And many people resisted this very strongly: they said 'Oh no, no! Latin is the language of the educated, the language of scholars, it's always been in Latin, and we must preserve the Latin! But some people argued, and I quote phrases that were used in this debate, that "Books in English would make better and easier learning. They would help students to proceed more cheerfully, more skilfully and easily forward in their studies. How many a common artificer (worker) is there in England who will be able by these good helps and information to find out and devise new works, strange engines or for the better maintaining of their own land". Those were arguments being used for the introduction of English as the language in which textbooks should be written in England. At University level you have a similar situation, somewhat later. Many of you have heard of Samuel Pepys, a very famous writer of diaries in England. In 1700 he was asked to comment or a letter from one of the Fellows at University College, Oxford, in which this University Professor was putting forward a new approach to teaching mathematics at the University. He proposed that the teaching of mathematics at Oxford should be in English instead of in Latin. However, he did promise to use Latin words and terms where they're necessary, because English was a limited language and had many deficiencies, it didn't have the vocabulary necessary for teaching mathematics properly and so they would have to use Latin words where the English words didn't exist. Such a revolutionary proposal worried Samuel Pepys. While he himself was in favour of teaching in English, he was worried because he thought that it might affect the honour of the University to teach in English. Well fortunately I think 300 years later we can say that the honour of the University of Oxford didn't suffer unduly by changing from Latin to English. But it is also worth noting that a School Certificate qualification in Latin

was a condition of entrance to Oxford until very recent years. So if your progress with language problems in PNG appears to be rather slow, do not be too discouraged; it took Oxford nearly 300 years to change completely from Latin to English. Even now, formal university ceremonies still take place in Latin.

But to return to PNG. There are two African countries that have or have had similar policies. One is Zambia, where all school education is in English. The reason for this is the diversity of mother-tongues. Zambia differs from PNG, however, in that an African language is taught as a compulsory subject at both primary and secondary levels.

The other country that experimented, on a limited scale, with English as the medium of education from Primary 1 was Kenya. The experiment was fairly quickly abandoned. The implication seems to be that PNG is faced, faut de mieux, with what is technically an exceedingly difficult situation.

I now turn to a few specific projects in this field.

The Yoruba Project

The primary schools around the University of Ife, Western Nigeria, have been the subject of a fascinating experiment in recent years. Yoruba is the name of both the people and the language in that region. What they did was to try and test whether pupils learnt better if they were taught in their mother-tongue through the whole of primary education, or if they learnt better by changing to English at Primary 4 level. The latter was the national policy, but the university was granted permission to conduct this experiment in some schools, to continue teaching in Yoruba right through primary education. The materials were written in Yoruba, translated into English for half the schools, left in Yoruba for the other half, and a comparative experiment done. The same examination was set at the end of Primary 7, written in Yoruba, and translated

into English for whose who had been using English. The results of this experiment in all subjects were compared. You may wonder what the results of those experiments would be. Maybe it would be different in different subjects? Maybe the Yoruba-taught children would do better in the arts subjects, the literary subjects, "writing" subjects, the social studies subjects, religious knowledge, while in mathematics and science perhaps the ones who had been taught in English would do better. But not so. The results were uniformly better for those children who had been taught throughout in Yoruba.

I don't think the implications of that are as obvious as may at first seem, because you have several other factors which are important to those children. Secondary education is in English. What happens to those two groups of children when they go into Form 1? A very different story. What happens when they look for job? You see there are all kinds of other factors, but in terms of cognitive development through their primary education, the result has been very clear.

Lesotho

Lesotho has a monochrome language situation, Lesotho being the universal mother-tongue and the language of early education. English is used as the medium language from Primary 4. The National University (NUL) has mounted a series of research studies in this field in recent years, and have organised two excellent workshops to analyse the issues in detail and to produce material for the guidance of teachers of science and mathematics, particularly at the lower secondary level. The report of the first of these workshops will be available at the Seminar.

Melbourne

One particular problem that many maths teachers in primary schools face is the problem of digit reversal. Children write seventy-two as 27, and fifteen as 51. This is a

problem in Britain, and I think in many language situations. There was recently a research study undertaken in Melbourne. Melbourne has many different immigrant groups, mostly from different European countries. These immigrant groups retain their own language at home, even though they may be taught in English at school. It was hypothesised that this digit reversal problem was related to language. Different language groups were tested and the results were interesting. Consider the number words in English. There is not much problem up to twelve. For higher numbers, like forty-five, the word comes in the same left-to-right (and spoken) order as the numeral 45. First comes "four", then the "five". But what about the "teen" words? "Teen" is obviously "ten", so in "sixteen" you are saying the "six" first, then the "ten". Is it surprising, then, that many young children write the 6 first in the numeral, ie 61? It is a well-known fact among primary teachers in England that this digit reversal is far more common in the teens than it is anywhere else. Many primary teachers say 'Oh that's because children get to the teens first, they learn the single digit numbers and then the teens, and this is where they're making their mistakes, they get it sorted out by the time they are using 20s so there's no problem then'. I wonder if it's not much more closely related to the fact that it's only the teens in English in which you get the words reversing? This experiment in Melbourne was designed to test this hypothesis. What about other languages? Consider German. Where do you think the main digit reversal problems would be in German? In German you have this reversal right the way through. It was found in the Melbourne experiment that pupils whose mother-tongue was German were far more prone to reversal problems than pupils whose mother-tongue was, for example, English.

What about Dutch? Again in Dutch this digit reversal problem was very common right through, closely matching the structure of the language. And of course, because Afrikaans originates from Dutch, this is also a problem in South Africa. Afrikaans-speaking children have a lot of trouble with digit reversal; although the language differs greatly in detail from Dutch, its general structure is still preserved in it.

You don't get this reversal problem in the words in French, and in this Melbourne experiment the children from French-speaking homes hardly had the problem of digit reversal at all. You can trace this close correlation between the number-words and digit-reversal problems in young children across various other languages; the Melbourne experiment also did it for Italian and for Spanish.

Singapore

In Singapore four different languages are spoken widely: English, Bahasa Malay, Chinese and Tamil. There are four kinds of schools using these four media basically, but in all the schools, mathematics and science are taught in English from the start. There was a fascinating project a few years ago called the Primary Pilot Project (PPP). English is taught as a subject in all the schools. In the PPP it was decided that English would be taught in the early primary years, not as a separate subject on the timetable, but by teaching mathematics and science in it. So maths and science were being used as a vehicle for teaching English as well as for the teaching of science and mathematics themselves. The project was set up to develop appropriate teaching material. It consisted of teams of science teachers, maths teachers and English teachers and they had to develop these materials. The maths and science people would write their materials and then they would be gone through by the English specialists, who would say 'No, you can't teach that in that way, because the children don't know that language structure'. There was constant argument and compromises within the writing teams and eventually the mathematics and science materials were developed in parallel with the development of the English structures needed for it. I think that is a very good example of how things should be done, rather than subjects being developed in isolation, particularly in isolation from language development.

Incidentally the Singapore Ministry of Education recently issued an edict which said that "....the decision by the Ministry of Education that scientific concepts should not be introduced within the first two years of the child's formal education. These two years should be devoted to building up vocabulary". That means science vocabulary. Isn't that extraordinary? You musn't introduce any science concept, you just build up the basic scientific vocabulary. I can't tell you what's happening as a result of that; it was in 1979 that that edict was issued. It would be fascinating to see how teachers managed to teach vocabulary without teaching any concepts at all.

'Deficient' languages

There is enormous danger in referring to any language as being deficient. It annoys me intensely when sometimes I hear people say 'Oh, such and such a language, Bahasa Malay, Swahili, whatever it may be, is deficient for teaching science and mathematics'. I think this is very dangerous and very misleading. I was speaking to someone in Australia recently who had been doing some work with languages of the Aboriginal people of Australia. These are very simple languages in many ways, they have a limited vocabulary, but to describe them as deficient languages is, I think, dangerous. This person was pointing out what would happen if an Aboriginal Australian living in the central deserts of Australia decided to do some anthropological research on some of the faculty members of the University of Sydney to test their conceptual development. They would start by making a questionnaire. You know how one of the things that anthropologists do when they're trying to find out about people from a different cultural group is to look at their language, the way they use words, the ideas present in their language, the language structure and so on. They try to analyse the language and so work back from that and say 'how do these people function cognitively?' - a complicated expression which means 'think'. So this Aboriginal Australian would make a questionnaire out to these University staff in Sydney and ask them questions like 'Are there 8 sub-

divisions in your clan system? Yes or no?' 'If no, how many sub-divisions are there?' The faculty member in Sydney would have to say 'No there are not'. How many are there? He leaves it blank, he can't answer it. 'Ah', the Aboriginal Australian says, 'this person has no idea of classification, there is no hierarchical concept in his mind, he is very undeveloped.' Question 2 on the questionnaire: 'What word do you use for a person who is running away from you? What verb?' Next question 'What word do you use for one running towards you?' Next question 'What verb do you use for somebody running across you, with his side to you?' Answers 'Running, running, running'. 'Ah' says the Aboriginal Australian (who of course has three completely different words in his language for this). 'Ah', he says, 'they've no idea of direction, no spatial concepts at all. They are a very backward people!'

Linguistics specialists assure us that any language has the capacity for development to the point where it can bear the weight of whatever demands are made upon it. I see no reason to doubt that assurance.

Finally, a little story from the Isle of Skye, off the coast of Scotland, to show that all developing countries seem to have these problems. The tribal language there is called Gaelic. One day a former teaching colleague of mine was on holiday on the Isle of Skye. He met a small boy, and asked him, "Do you learn mathematics in Gaelic at school?" "Oh yes", replied the boy, "except for subtraction, which we do in English".

REFERENCES

Nairobi Conference, *Interactions Between Linguistics and Mathematical Education:* report of UNESCO - CEDO - ICMI symposium. UNESCO, Paris, 1974.

CASME, *Languages and the Teaching of Science and Mathematics with Special Reference to Africa;* report of a CASME Seminar, Accra, Ghana. CASME, London 1975.

AUSTIN, J.L. and HOWSON, A.G. *Language and Mathematical Education* Reprinted by SMP London 1980, from *Educational Studies in Mathematics* 10, 2, 1979.

National University of Lesotho, *Language in the Mathematics and Science Lesson,* parts 1 and 2. Report of a workshop, January 1980. Department of Science Education, NUL, Roma, 1980.

WILSON, BRYAN. *Cultural Contexts of Science and Mathematics Education.* Centre for Studies in Science Education, the University of Leeds, 1981.

Community School Mathematics Teaching And Curriculum Innovation in Papua New Guinea

Randall Souviney
Indigenous Mathematics Project
May 1981.

Presented at the Mathematics Education Conference at the University of Technology, Lae, Papua New Guinea, 6–7 May 1981.

COMMUNITY SCHOOL MATHEMATICS TEACHING AND CURRICULUM INNOVATION IN PAPUA NEW GUINEA.

ABSTRACT

A summary of research carried out in five community schools under the auspices of the Indigenous Mathematics Project is reported. Achievement, cognitive and classroom observation data are discussed with recommendations made regarding the revision the current Mathematics for Community School syllibus and subsequent textbook production.

It was concluded that the prompt introduction of an appropriate, locally developed textbook for grades 4-6 and comprehensive teacher handbooks for grades 1-3 would, in conjunction with adaquate inservice training, have significant effects on teacher competence and student achievement. The results were especially encouraging relative to potential gains in rural and extreme-rural settings.

Community School Mathematics Teaching And Curriculum Innovation In Papua New Guinea

Several results are presented in this paper which, if interpreted reasonably should offer insight into the complex task of improving primary mathematics instruction in Papua New Guinea. The data was collected over the past two years as part of the ongoing Indigenous Mathematics Project research and development efforts. Attempting to summarize and interpret as large a body of data as reported here is, however, fought with the dangers. On the one hand it is possible to claim that a result supports a particular recommendation when in fact the conditions surrounding the events are so unique that situation and hence the recommendation would not be applicable to other settings. Alternately it is statistically possible to show a significant difference between almost any two groups if a large enough sample (say more than 1000) is included in the study.

The "effect-size" (ie: difference between the mean scores) might be extremely small even though the statistical test would show the means to be significantly different. To educators the effect-size attributable to curriculum change is as important as whether differences in achievement are statistically significant. In other words achievement gains must not only be significant but must be of sufficient magnitude to warrent the effort associated with changing the instructional program.

Achievement Results

The current case study reviews the effects of curriculum innovation at five community school sites throughout Papua New Guinea. Several measures of achievement and cognitive competence were administered. Though statistically significant differences were found between schools the patterns of differences were not consistant. Highlands schools in

general showed lower achievement levels than the coastal sites. However, the Southern Highlands site clearly out performed all other sites in mathematics achievement. Though English competence was highly correlated with mathematics achievement, the site with the highest reading achievement scored second or perhaps third in overall maths achievement. The West Sepik subjects, who scored the lowest on most measures, performed admirably on the oral dictation exercise. Table 1 shows the pooled grade four and six mean achievement results for the five sites.

Table 1

POOLED GRADES 4 AND 6 MEAN ACHIEVEMENT BY SCHOOL (%)

Site	PMAT2	PMAT3	PMAT4	READ	DICT	n_{pmat2}
MP	60.7	65.1	64.6	85.3	88.0	52
WSP	51.9	59.0	61.0	75.3	89.7	52
SHP	65.7	68.7	70.7	83.5	88.3	65
WHP	53.3	56.7	59.1	74.1	74.6	67
NCD	59.8	61.7	63.5	86.0	86.6	64
$\bar{x}$	58.3	62.4	63.8	80.8	85.4	60

MP = Manus Province
WSP = West Sepik
SHP = Southern Highlands
WHP = Western Highlands
NCD = National Capital

PMAT2 = pre-test
PMAT3 = post-test
PMAT4 = retention-test
READ = sentence completion test
DICT = oral dictation test

The two most rural sites (West Sepik and Manus) exhibited little similarity in their achievement profile suggesting that proximity to provincial education services may have only a contributing influence on student achievement.

Achievement scores indicated significant gains in all three grades over the [illegible] week trialling period (Table 2). The average gain was 4.6 percent across the implementation period and 1.9 percent during the reten-

tion period. Significantly more growth took place during the observation period ($T = 5.1$, $p < .001$)

Table 2

Delta 32 and Delta 43 By Grade ($\bar{x}$)

Grade	DELTA 32	DELTA 43
2	7.8	0.9
4	3.1	1.0
6	3.7	2.5
$\bar{x}$	4.6	1.6

DELTA 32 = PMAT3 - PMAT2
DELTA 43 = PMAT4 - PMAT3

The variance associated with PMAT2, PMAT3 and PMAT4 also offers some encouragement with regard to the success of the implementation. The standard deviation decreased from 17.2 for PMAT2 to 16.0 for PMAT3 (Table 3). Since the mean increased for PMAT3 and the top scores did not change significantly, we are left with the conclusion that the subjects on the lower end contributed more to the mean gain than those at the top.

Table 3

Mean Achievement By Grade

Grade	PMAT2	PMAT3	PMAT4	READ	DICT	n_{pmat2}
2	30.1	36.9	38.4	47.3	24.9	114
4	52.6	55.7	56.8	74.9	81.1	157
6	64.3	68.8	71.1	86.3	89.3	143
Grand $\bar{x}$	50.4	54.6	56.9	75.3	72.8	138
SD	17.2	16.0	16.5	19.5	27.9	

SD = standard deviation

We conclude that the curriculum contributed more to the growth of the average and below average children. It can be argued that subjects receiving the lowest scores on the pre-test could show greater gains since they are confronted with relatively simple previously missed items while the students at the top are confronted with the more difficult missed exercises. The fact that grade two gained about twice as many percentage points as grade four and six from PMAT2 to PMAT3 could be interpreted to support this contention. However, even though the mean continued to increase from PMAT3 to PMAT4 the standard deviation increased to SD = 16.5 implying a broadening of achievement spread during the retention period.

We conclude that the highly perceptual learning aids (base-10 materials, coins, squared paper, kina cards, etc), the student activity books and small group class organization contributed to the reduced variance in student achievement during the trial period. The difference between the top and bottom school based on pooled grade four and six achievement scores also decreased more between PMAT2 and 3 (13.8% to 12.0%) than between PMAT3 and 4 (12.0% to 11.6%). Though it appears that IMP's involvement at the five sites positively effected overall mathematics achievement the question remains as to whether to attribute this growth to the curriculum, the preliminary inservice course or simply the motivation associated with the presence of the full-time observer. We suspect the combined interaction of these factors contributed significantly to the surge in the achievement.

A significant difference was found between sites based on pooled grade four and six PMAT2 results ($F = 1.73$, $p<.001$). The five sites divided into two homogenous subgroups with the Southern Highlands, Manus and National Capital sites achieving significantly higher than the Western Highlands and West Sepik sites. Similar results were found for Reading ($F = 11.3$, $p<.001$). Significant differences were also found between

sites with regard to Dictation scores as well ($F = 26.5$: $p<.001$) though suprisingly the West Sepik site ranked above all the other sites. Perhaps the extensive use of NBC radio broadcasts throughout the year at this extremely remote site had it's effect on the results of this measure.

It is interesting to note that due to prior research we expected the National Capital District and Manus site to attain higher achievement scores than the highland sites. The Southern Highlands school however, consistantly outperformed all other sites in mathematics achievement.

As expected reading achievement was higher in the coastal regions than the highland sites. Though there is a reasonably high correlation between pooled grade four and six PMAT4 and Reading scores ($r = 0.67$) the relationship is by no means linear. SHP achieved higher means in maths (significantly in grade six) than NCD while the situation in reversed for the Reading results. Reading ability seems to have a strong positive effect on mathematics achievement up to an unspecified threshold beyond which some other factor (possibly reasoning or problem solving ability) comes into play. Improving language skills in the lower grades may therefore elicit a greater effect on mathematics achievement than in the upper grades where threshold language skills necessary to support mathematics learning have been attained to a greater extent. This contention certainly deserves further attention and could provide a basis for practical solutions to persistant instructional problems. More stress on the explicit development of mathematical vocabulary and appropriately grammar would seem central to any effective primary syllabus.

A native English speaker may take for granted expressions that are confusing to the second language speaker. For example the members of a recent workshop in Goroka, PNG, compiled the following list of English

expressions which designate subtraction:

1. Six subtract three.
2. Subtract three from six.
3. Take three from six.
4. Six minus three.
5. Six take away three.
6. Six less three.
7. What is three less than six.
8. Decrease six by three.

Though all eight expressions suggest the subtraction problem 6-3, the syntax can be very confusing to second language speakers (and many native English speakers as well).

Attention must be given to the obvious problems children encounter as they endeavor to understand the highly technical, relational language required in mathematics. It must also be remembered that for many students English is their third, fourth or in some cases fifth language.

No viable alternative to English as the language of instruction seems to be available. It has been reported that as many as 80% of the student population in Papua New Guinea could be serviced with as few as 8 of the over 700 languages represented (including English). The decision to encourage a wider range of acceptable languages of instruction has political as well as pedagogical ramifications. Decisions on language usage will continue to be a political issue though educators have long argued their case for rationalizing the use of languages in the learning process.

A viable compromise might involve assigning wherever possible, teachers in grade one and perhaps two who speak the local vernacular. Specific

inservice training would be required in methods of using tok ples as a basis for developing technical terms and grammar in English.

Such an effort would by necessity be transitional in nature in that by the end of grade two all instruction would be in English. Language development would also be enhanced by the conscious effort to relate English concepts to their tok ples analogs. At worst such a decision would simply sanction a procedure already in common practice. We encountered frequent attempts on the part of teachers who didn't understand tok ples to explain a difficult concept by switching to Pidgin. It seems that when teachers become frustrated with children who don't understand an idea in English they switch to any second language even though in this case the class did not understand Pidgin any better than English!

Certainly a persuasive argument could be made to encourage the posting of teachers to schools where they speak the local vernacular in order to work with grade one and possibly grade two children. In lieu of a qualified vernacular speaking teacher, a local grade eight school leaver could be recruited as a teacher's aid especially in extremely rural sites. Both the children and the school leavers would benefit greatly from such an arrangement.

Cognitive Competence

A strong relationship appears to exist between cognitive competence and mathematics achievement. By combining the results from two conservation tasks (conservation of number and length) with the two classification tasks (logical classification and class inclusion) an overall measure of cognitive competence (COGT) can be computed. Justification for this procedure can be found in Mpiangu and Gentile (1975) and Englehardt and Weibe (1980). Table 4 lists COGT and PMAT2 means by site.

Table 4

Cognitive Competence By Site

POOLED GRADES 2, 4 AND 6

Site	COGT ($\bar{X}$)	PMAT2 ($\bar{X}$)
MS	6.7	50.9
WSP	4.6	42.3
SHP	6.7	56.4
WHP	5.6	48.1
NCD	6.6	48.9
$\bar{X}$	6.0	50.9

COGT = Total Cognitive measure (CN + CL + LC + CI)

The simple correlation between COGT and PMAT2 means across sites is (r=.85). The result indicates that approximately 72% of the variability in group mean achievement scores can be accounted for by the overall cognitive competence measure. This result seems highly significant however we reserve judgement until analysis is completed using the subject as the unit of analysis.

Item Analysis Mean achievement results are only useful for comparing sites, grade levels and overall changes in achievement. In order to evaluate understanding of specific mathematics content it is necessary to look at individual test items and their relationship to subject-matter topics. PMAT items can be grouped under four content strands:

1. Measurement (11 items)
2. Number and Operations (36 items)
3. Mathematical Language (7 items)
4. Problem Solving Applications. (8 items)

Computing achievement growth in each of the four content catagories offers a clearer picture of the learning profile. Table 5 gives the

mean percent of correct responses for PMAT2 and 3 by content strand.

Table 5

Item Analysis By Content Strand

PMAT2 and 3

Content Strand \ Grade	2		4		6		$\bar{X}$ pool	
	PMAT2	PMAT3	PMAT2	PMAT3	PMAT2	PMAT3	PMAT2	PMAT3
Measurement	49	58	70	78	83	85	71	74
Number and Operations	32	41	60	65	73	81	56	63
Mathematical Language	46	53	70	75	78	83	66	71
Problem Solving Applications	0.1	0.1	6	4	18	18	9	8
$\bar{X}_T$	30	37	53	56	64	69	50	55

$\bar{X}_{pool}$=mean grades 2,4 and 6

$\bar{X}_T$=mean across all strands

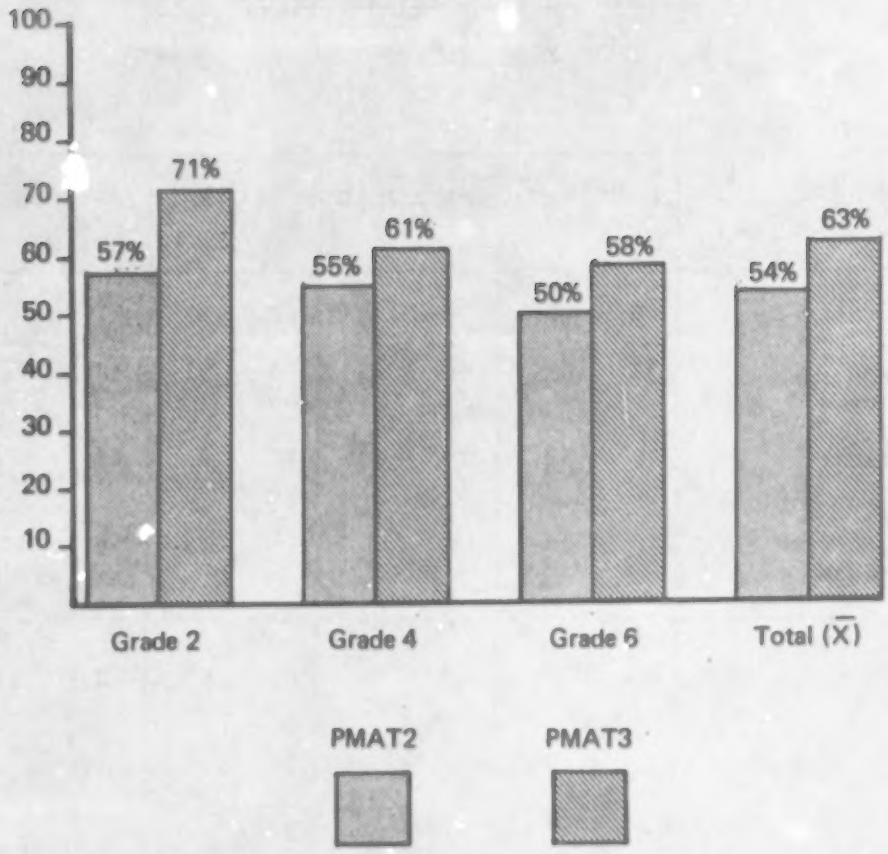
The results clearly show that this group of subjects are far more competent at items involving measurement, number operations and mathematical language than those involving problem solving applications. Also, significant achievement gains are attained at all grade levels for all strands except problem solving.

Further clarification is provided by Figure 1 which shows the mean percent of correct response on test items designated as grade level objectives. Of the 62 PMAT exercises 33 addressed grade two objectives, 31 for grade four and 37 for grade six. (Some objectives overlapped grade levels due to the reintroduction of selected concepts at later grade levels).

Figure 1

FREQUENCY GRAPH OF ACHIEVEMENT BASED ON GRADE LEVEL OBJECTIVES

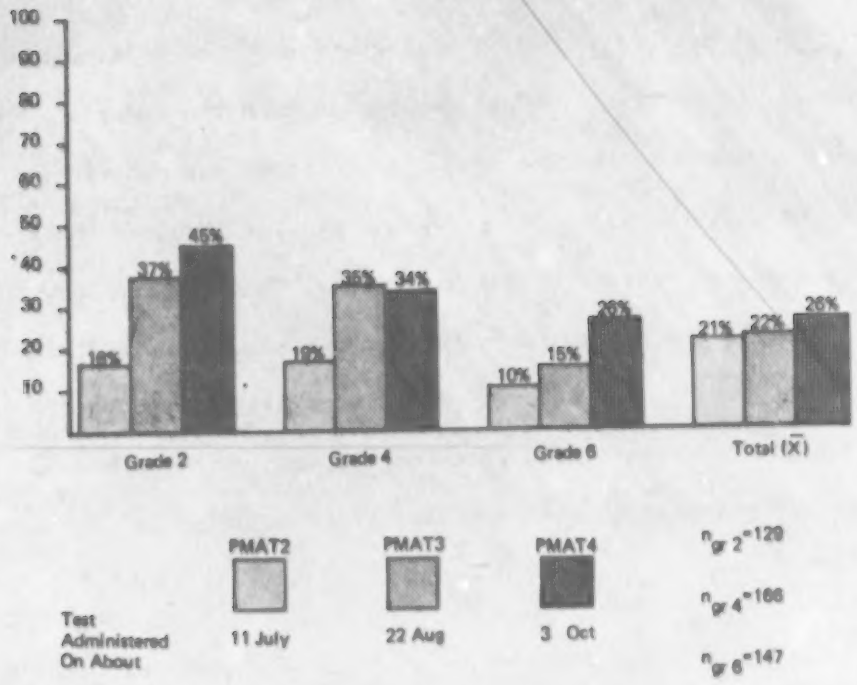
GRADES 2,4 AND 6



Again, significant increases in achievement are noted across the six week trialling period but a different trend becomes apparent. Grade two children achieved a mean of approximately 71% on appropriate grade level objectives on PMAT3. Grade four achieved a mean of about 61% and grade six 58%. We conclude that as the content increases in difficulty in upper grades overall achievement on grade level objectives decreases. Finally Figure 2 shows the percent of children attaining a mastery level of 80% on grade level objectives. Results are presented for PMAT2, 3 and 4.

Figure 2

FREQUENCY GRAPH OF SUBJECTS ATTAINING 80% MASTERY LEVEL ON GRADE LEVEL OBJECTIVES GRADES 2, 4 AND 6



The percent of students attaining grade level expectations decreases from grade two to grade six. The percent attaining mastery consistantly increases however over the three testing periods (11 July, 22 August, 3 October). These results are relatively encouraging when compared to results reported from previous achievement studies (Roberts and Kada, 1979; Edwards and Bajpai, 1979).

LESSON IMPLEMENTATION

In addition to the instruments described above, extensive field notes were compiled by trained observers. Significant classroom events were documented over the entire six week trialling period (Gearhart, 1980; Johnson, 1980; Levin, in press; Lineberger 1980; Rowe, in press). In reviewing the observer's notes several problems became apparent which seemed to interfere with instruction at the majority of sites. The

problems fall into three general catagories; instructional materials, classroom management, and subject matter content.

Instructional Materials: All the teachers had some difficulties co-ordinating the various elements associated with the lessons. Each teacher responded to the challenge in their own way and with varying degrees of success. The most prevelant problem involved the preparation, distribution and storage of learning aids. Those aids prepared by the IMP staff (die-cut cardboard base-10 materials, coins and kina cards, measurement devices and squared paper) were all shipped to the sites beforehand. These materials were for the most part punched out by the teacher and packaged in the envelopes provided prior to the beginning of term 3. No serious problems occured.

Where difficulties did arise was with materials designed to be prepared by the children themselves. The time seriation cards in grade two proved to be too difficult for the children to trace or draw. The resulting lesson took far longer than is justified. Attempts to circumvent the problems by using words instead of pictures was successful at two of the sites. One teacher reproduced copies of the worksheet for each student and the lesson proceeded as planned. Duplicating machines are available at a very small percentage of community schools. Two teachers suggested that sequence stories could be drawn by the children during art or language class and used in maths for seriating timed events.

Children, especially in grade two, spent considerable time drawing place-value tables on squared paper in preparation for practice exercises. Though the tables proved useful in helping the grade two children develop and practice place-value and arithmetic skills, an

unacceptable amount of time was taken up setting out their work. One of the causes seemed to be that the children had been instructed to be very accurate in their drawing and writing which in this case greatly reduced the time remaining for arithematic skill practice - the primary objective of the lesson.

Unless children can be encouraged to sketch the place-value tables more quickly (even at the expense of accuracy), the use of consumable worksheets should be considered at least for number work in the lower grades. A small booklet of worksheets (approximately 64 pages) could be produced locally and supplied to each child in rural schools. Urban schools could duplicate the worksheets at the school site minimizing costs and shipping logistics. Upper-grade children who have developed greater dexterity had little difficulty setting out their exercises on squared paper.

In grade four, students were asked to cut out 45 squared paper multiplication blocks. These materials took from one to four class periods to prepare. Though they were used for several lessons and in general proved useful in developing and practicing the multiplication table, the time required to actually produce the aid seems unjustified. The aid could be easily produced at the Department of Education Materials Production Center and distributed to schools for use as flash cards.

In grade six a similar problem occured with the production of place-value number cards. Again these materials proved to be useful aids but the time required to construct them did not seem justified.

Locally produced learning aids are certainly useful in teaching difficult concepts but the time and expense involved in construction must be balanced against potential utility. If the aid is to be used in only one lesson, preparation time must reasonable or at least construction

must take place outside of class time - unless of course other objectives can be met at the same time (e.g. learning to use a ruler and scissors).

Classroom Management: Several teachers initially exprienced considerable difficulty in distributing aids and materials during the lessons. The process took up an excessive proportion of class time during the first two weeks. The situation improved considerably when teachers began to give students the responsibility for distributing materials while the teachers prepared the board for the lesson introduction. If the teacher was working in one room, as is generally the case, as opposed to dividing his attention between three classrooms, the materials could be stored in the classroom and monitors could be assigned to distribute aids and materials at the appropriate times. Storage will continue to be a problem in bush schools because of the damp climatic conditions. A water-tight plastic container would go far in protecting the cardboard aids. Simple manila envelopes helped keep the student sets of base-10 materials and similar aids organized for easy distribution. Materials of this type could be mailed directly to schools in their storage envelopes.

Another classroom management problems involved organization for small-group instruction. Group work (2 to 6 students) seemed to be an effective means of engaging children in skill practice games and concrete experiences with learning aids. Teachers initially experienced some difficulty effecting the transition between the large group lesson introduction and subsequent small group follow-up activity. Teachers often attempted to introduce an activity with the children already broken into groups. This situation frequently caused confusion since the groups lacked an understanding as to how to proceed. The teacher then had to give basic instructions to each group in turn. This process

caused considerable disruption as groups waited for instructions from the teacher.

The problems were alleviated by suggesting that the teacher consistantly begin each lesson with a large group demonstration involving the entire class working together through the same exercises or games. When most of the children demonstrated an ability to carry out the process on their own, the class subsequently broke into groups with a leader appointed at each to distribute materials. The teacher then visited each group starting with those that experienced the greatest difficulties in the past. If general problems became apparent the teacher once again offered a whole class demonstration to clarify the situation.

One major oversight with regard to instructional materials involved difficulties experienced by teachers in displaying appropriate manipulations of the learning aids during whole-class demonstrations. Teachers made do with sketches on the chalkboard but the process of sketching base-10 models for number operations was time-consuming and somewhat more abstract than the actual concrete manipulations. We have attempted to alleviate this problem by introducing a magnetic display board. A piece of galvernised sheet steel (50cm x 100cm) painted with green chalkboard paint made an excellent surface on which the teacher could chalk place-value tables and manipulate magnitized base-10 materials, coins and other aids. One or more small pieces of a rubber magnet strip removed from the gasket of an old refrigerator door was glued to each cardboard piece. The display stands on the board chalk tray. Place-value tables can be drawn on the board next to the display to carry out the corresponding symbolic manipulations.

Magnetic Display Board

If sheet steel is not available, the side of a metal cabinet can be painted and positioned next to the chalk board. We found this system to be a most useful and inexpensive visual aid wherever old refrigerators and sheet metal can be found locally.

Overall the activities and instructional aids were well-received by the teachers and effectively utilised by the students. The reasonable production and shipping costs associated with the materials should keep initial investment and replacement within limited budget constraints. The die-cut cardboard manufacturing technique should have a wide application in other subject areas as well. A stencil map of Papua New Guinea has already been approved for trial distribution. Punched card aids along with a magnetic display board provide an inexpensive, versatile visual display system for classrooms even in the most remote regions of the country. It is important that all instructional materials be supplied with a simple teachers guide keyed to the course syllabus. The guide should be prepared with the idea that it will be used by headmasters, senior teachers and curriculum personnel as a basis for

inservice instruction for practising teachers.

Finally a general problem encountered by many of the teachers involved ongoing evaluation of individual student progress. Formal and informal assessment of student achievement varied across sites. With the possible exception of the WHP teacher, the teachers were far from consistent in their efforts to determine the success of individual children in meeting lesson objectives. Rarely were individual students asked to respond to questions or observed working in small groups. Little ongoing evaluation of student understanding took place during the course of instruction. The teachers generally characterized a successful lesson on one that progressed smoothly and in which all the material was "covered".

Teachers seemed to interpret chorused responses from the class as appropriate measures of understanding. Few criteria-referenced tests were administered by the teachers. Term tests however were set about four times each year in order to compare overall achievement. The results seemed to serve as a means for categorizing children (especially in the upper grades). They were rarely used as an aid in determining what specific skills individual students were lacking, as a basis for altering instruction, or as a criteria for forming appropriate instructional groups.

Clearly a series of brief (5 to 8 exercises) criteria-referenced tests should be included in any planned testbook. The tests should appear in the text and be administered every week or two. They should be designed in such a manner as to encourage the teacher to use the results in planning future instruction. A simple record-keeping system should be described in the teachers guide to help teachers keep track

of individual student progress. Topic or term tests could also be included to provide broader indicators of achievement and placement. Because of the difficulty in analysing the large number of items and the length of time between setting for these exams, it is unlikely that the results can be effectively used to benefit individual understanding of mathematics. It would be inappropriate, in our estimation, to attempt to use topic or term tests for the purpose of making class-level instructional decisions.

Subject Matter: Based on our results several recommended changes in the current community school syllabus seem advisable. First we feel strongly that the current stress on multibase arithmetic in inappropriate. Conceding that Dienes' multiple representation model has considerable theoretical support when applied under ideal instructional conditions, we contend that the application of the theoretical model to actual classroom use has met with little objective success in Papua New Guinea. Misunderstandings regarding the purpose of multibase arithmetic abound. Those teachers who possess a good grasp of the methodology often treat each base as a mastery objective rather than interum steps leading to base-ten operations.

Aside from the argument as to whether the method is effective in teaching computation, the fact remains that the multibase blocks necessary to effectively implement the program are for all intents and purposes "extinct" in PNG. Substituting the more symbolic representation of exchange games using sticks, leaves, stones and shells is at best a poor substitute and at worst may simply increase the already overwhelming amount of disconnected school talk to be memorized.

We suggest as an alternative the development of numeration focussing almost exclusively on base-ten operations with perhaps base-three and base-five exchange games introduced early in the development of place-value. Structured base-10 materials (die-cut cards or locally produced seed-canoes), coins and squared paper arithmetic provide the necessary developmental transition to symbolic arithmetic. All algorithms should be developed with consistent reference to place-value and regrouping. This process should provide a consistent basis for whole number and decimal work (Souviney, Keyser and Sarver, 1979). Ratio fractions should be introduced to provide the necessary language for defining partitioning, equivalent families and the introduction to decimals. Operations with ratio fractions should be kept to a minimum (i.e. addition and subtraction with like denominators, multiplication and division of a fraction by a whole number).

We also recommend a change in emphasis regarding the development of set theoretic and relational concepts. Rather than focussing on the underlying class or logical structures we suggest the curriculum directly address the surface language behaviours (English vocabulary and grammar) necessary for effective communication in mathematics. This suggestion is more a change in perspective than content. We envision employing activities similar to those in the current curriculum used for developing relational concepts of comparison, ordering, classifying and predicting. The differnece lies with the manner in which the teacher describes the purpose of these experiences to himself and to his students. The objective becomes one of developing language skills (the value of which is already appreciated by the teacher and students) as opposed to making explicit the ideas underlying the logical structure itself (i.e. clock games as models for cyclic groups).

Measurement and geometry seem fairly well developed in the current curriculum. The introduction of metric units should be coordinated with the science syllabus and should be phased in during grades four, five and six. Comparison activities should be used to introduce each measurement attribute (length, area, volume, weight, time, temperature, speed). Locally developed units of measure (either school based or traditional units) should be used to extend the notion of measurement beyond simple comparison and ordering. Finally metric units should be introduced as standard units of measure (Keyser and Souviney, 1980; Hughes, 1981).

For practical purposes litre measures of volume are preferred over cubic units (i.e., cm^3, m^3). We also feel the benefit of making a distinction between mass and weight is probably not worth the effort at this level. We suggest simply using the term weight throughout.

Geometry should progress from topographical concepts such as inside and outside to enclosed polygons, shapes, tesselations and patterns, the study of triangles and parallels, solid figures and the conventions of perspective drawing. This latter topic has received considerable attention in research carried out in PNG (Bishop, 1979; Clements and Lean, 1980) and should be an important objective associated with geometry in grades four through eight.

The final strand which should be represented throughout the syllabus is problem solving applications. Application problems are characterized by relevance to everyday life and generally involve bringing one or more well-defined measurement or number operations to bear on elements given in the problem description. Often we describe the problem in story form where all the necessary information is embedded in the

language structure. Other times data must be extracted from the environment in order to effect a solution. Of the five strands none are as important or as poorly understood as problem solving. The ability to solve story problems is closely tied to language skills. A three step process should be employed to assist children with solving such problems:

1. Give the solution to a story problem and ask the student to indentify the phrase that indicates what operation to use.

   Problem: Venna has 6 toea. Hai has 10 toea. How much do they have altogether.

   Hint: You need to add to solve this problem. What word(s) tell you to add?

   Answer: How much altogether.

2. Ask the student to determine what operation to use to solve a problem without actually computing the answer.

   Problem: Twelve people wanted to go to Loloata Island. A canoe carries only 4 people each. How many canoes were needed for the trip.

   Answer: Divide

3. Have the student solve the word problem using the information given.

   Problem: A truck can carry 750 kilograms of cargo.
   A bag of coffee weighs 50 kilograms.
   How many coffee bags can the truck carry.

   Answer: 15 bags
   50)750

Beginning problems should be designed to be solved in one operation with all the necessary information included. Later problems requiring two or more operations can be attempted. Extra information not used in the

solution should be included later as a distractor. Problems should be drawn from all the content strands: number and operations, measurement, geometry, logic and sets. Aids to problem solving such as sketches, graphs, estimating, trial and error, looking for patterns and functions should be systematically introduced (Souviney, 1981).

Textbook Production

The results of the current study offer convincing evidence that the teachers involved were capable of effectively coordinating student activity books and learning aids. There were, however, definite limits as to the number of elements the children were capable of managing efficiently. The teaching suggestions provided for each lesson were used by all the teachers on a daily basis for planning purposes and during the lesson implementation. Teachers generally praised the specific hints and suggestions though there was a consistent request for more worked examples.

Some confusion seemed to be caused by our attempt to provide simple step-by-step instructions for certain lessons. For example in one exercise the numbered steps in the Teachers' Notes did not correspond with the exercise numbers. One teacher read this notes directly to the class as instructions. For example: "Number one. Look at your worksheet. Number two. How many fish does the man have?" The children looked at worksheet problem number two instead of problem one and were confused, along with the teacher, for the remainder of the lesson. Though only one of the five teachers experienced this difficulty the example points out the problems associated with writing a teaching "Script" that, when read to the children without interpertation, conveys the appropriate meaning.

Though we were not attempting to "teacher proof" the lessons the experience suggests that the curriculum writer must get into the playwrite business in a big way or avoid altogether carefully sequenced sets of instructions. Clusters of directions addressing critical sub-elements of lesson proceedures seem more appropriate. Subsequent synthesis of these key elements is then left to the teacher's judgment. Attempting to circumvent the teacher in such matters has time and time again been proved unsuccessful. Sets of instructions to teachers cannot substitute for good inservice education and teaching experience.

From our experience it seems clear that teachers and children even from the most remote sites would benifit greatly from the prompt introduction of an appropriate mathematics textbook. The content should reflect the rich cultural heritage of Papua New Guinea and address concepts which will be required for life in this rapidly developing nation. It seems vital that students be prepared to contribute effectively to village development should they not be selected to go on to secondary school. Likewise the needs of the growing percentage of children who are priviledged to continue their education cannot be ignored.

Kuperus (1980) concludes from work carried out in Cameroon, Africa, that since the vast majority of children in developing countries terminate their formal education after five or six years, the entire enterprise must be geared to preparing children for effective social and economic participation at the village level. Though stress must be placed on functional mathematics literacy, sufficient structure must also be present in the conceptual development of the content to support requirements of subsequent mathematical development necessary in commerce and secondary education. In other words, though it is

vitally important to incorporate relevant features of community development into primary mathematics education (i.e. designing and constructing rain water tanks, planning a trade store business, bookkeeping for cash crops-copra, cocoa, coffee, tea) these functional aspects of mathematical application are not sufficient in themself to constitute a mathematics curriculum. The functional activities would form a collection of unrelated ideas without some attention being paid to the underlying structure of number and measurement systems, regularities and patterns found in computation and geometry and the powerful medium of communication and prediction offered by graphs and statistics.

Clearly the issue of poor application of problems solving skills will remain unaddressed by a curriculum comprised exclusively of functional applications. Alternately a program of instruction which selects activities exclusively on the basis of elucidating the underlying logic and structure of the mathematical content seems totally unacceptable. Not only will the resulting knowledge be viritually untransferrable to the village development setting without a real world context, precious little learning is likely to take place at all.

In general the education literature indicates that the introduction of appropriate textbooks has a significant effect on mathematics achievement (Comber and Keeves 1973; Skukla 1974; Walker, 1976; Castro and Sanguinetty, 1977). The introduction of locally produced texts seems particularly important in the Papua New Guinea context. Results from the current study indicate that the student activity booklets ameliorate to some extent the problems associated with non-native language instruction for children in extreme rural areas and for grade two students in general. These groups showed greater achievement gains than the older and more urbanized children. We infer than that a textbook with an appropriate

language load would enhance community school achievement particularly in extreme rural areas where current teaching conditions and lack of materials interact with poor English skills to create an imbalance in mathematics achievement.

Plans For the Future

We plan to recommend a set of grade level behavorial objectives organized into five strands.

Recommended Content Strands

1. Number and Operations
2. Mathematical Language
3. Measurement
4. Geometry
5. Problem Solving Applications

This set of objectives will be offered as a starting point for revising the current community school mathematics syllabus and for textbook production. We will endeavour to structure the content in a manner consistent with observed development and achievement levels of children in Papua New Guinea. Efforts will be made to articulate the primary objectives with those of the new grade 7 and 8 textbooks (Britt, 1980; Hayter, 1980).

Clearly the task is not completed. With generous World Bank support textbook production for grades four, five and six is about to get underway. We are proposing that the joint efforts of the Department of Education, UNDP/UNESCO and UNICEF be employed in producing comprehensive teacher handbooks for grades one through three. The results of this effort would be used to assess the feasibility of developing student textbooks for grades two and three and perhaps grade one.

REFERENCES

Bishop, A. "Visualing and mathematics in a pre-technological culture." Educational Studies in Mathematics. 10 (2), 135-146, 1979.

Britt M. "Secondary Mathematics - a curriculum development project." Indigenous Mathematics Working Paper Series, Department of Education, Papua New Guinea, No. 5, 1980.

Castro, D and J. Sanguinetty. "The determinents of schooling and education performance in Latin America". Paper presented at the Bellagio Conference, 1977.

Clements, K and G. Lean. "Spatial ability, visual imagery and mathematical performance." Mathematics Education Center Report Series, University of Technology, Papua New Guinea, No. 10, 1980.

Comber, L. and J. Keeves. Science Education in Ninteen Countries. New York: Halsted Press, 1973.

Edwards A and A. Bajpai. "Preliminary report on the basic arithmetic test carried out in post-secondary institutions in Papua New Guinea." Mathematics Education Centre Report Series, University of Technology, Papua New Guinea, No. 6, 1979.

Englehardt, J. and J. Weiße. "Conservation of number and mathematics instruction with manipulative materials." Arizona State University, Tempe, Arizona, 1980.

Gearhart, M, "Community School Field Report." Indigenous Mathematics Project Working Paper Series, Department of Education Papua New Guinea, No. 8, 1980.

Hayter, J, "The high school mathematics curriculum in Papua New Guinea: An evaluation study." School of Education, University of Bristol, U.K., 1980.

Hughes, J., Grade Five Science Teachers' Guide. Department of Education, Papua New Guinea, 1981.

Johnson, K. "Community school field report", Indigenous Mathematics Project Working Paper Series, Department of Education, Papua New Guinea, No. 9, 1980.

Keyser, T. and R. Souviney. Measurement and the Childs Environment. Santa Monica: Goodyear Publishing Co., 1980.

Kuperus, P. "Towards a theory of primary mathematics instruction." Center National d' Education, Yaounde, Cameroon, 1980.

Levin, P. "Community school field report." Indigenous Mathematics Project Working Paper Series, Department of Education, Papua New Guinea, in press.

Lineberger, J. "Community school field report." Indigenous Mathematics Project Working Paper Series, Department of Education, Papua New Guinea, No. 7, 1980.

Mpiangu B. and J. Gentile. "Is conservation of number a necessary condition for mathematical understanding?" Journal for Research in Mathematics Education, Vol. 6, 179-192, 1975.

Roberts, R. and V. Kada. "The primary mathematics classroom", Papua New Guinea Journal of Education, Vol. 15, 174-201, 1979.

Rowe, B. "Community school field report". Indigenous Mathematics Project Working Paper Series, Department of Education, Papua New Guinea, in press.

Shukla, S. "Achievement of Indian children". Comparative Education Review, 18 (2), 237-247, 1974.

Souviney R., T, Keyser and A. Sarver. Mathmatters: Developing Computational Skills With Developmental Activity Sequences, Santa Monica: Goodyear Publishing Co., 1979.

Souviney, R. Solving Problems Kids Care About, Santa Monica: Goodyear Publishing Co., 1981.

Walker, D. An Empirical Study of Education in Twenty-One Countries, New York: Halsted Press, 1976.

LAWRENCE ROS
Goroka Teachers College

STANDARDS IN MATHEMATICS, A DEFEATIST POINT OF VIEW

(Abstract of paper given)

It is proposed that an influencial factor affecting the level of achievement in mathematics in government schools is the official transition rate, which is defined as the percentage of students who progress from the primary to the secondary level in the state supported education system. The data presented in an earlier paper (Ros,1980) provided strong prima facie evidence for believing that the higher this transition rate, the less selective state supported secondary schools are, and the lower the levels of achievement in mathematics in them.

Rogers has proposed (as a matter of urgency) to increase from four to eight the number of National High School, and that policy be laid down to augment this number in anticipation of high level manpower needs. In his report Rogers states;"It cannot be argued that there are too few of the proper quality to enlarge the intake to National High Schools". This paper provides evidence that this is not the case, and that the implemention of the Rogers proposals must lead to lower standards in National High Schools and would endanger the quality supply to tertiary institutions.

The following M.E.C. Reports have been published:

No. 1: A. EDWARDS 'Report for 1978, including a Short History of the Mathematics Learning Project and Mathematics Education Centre up to 1977', 1978 .

No. 2: A.J. BISHOP 'Spatial Abilities in a Papua New Guinea Context', 1978 .

No. 3: C. MEEK and N. FERIL 'A Pilot Study into the Level of Comprehension of Some Words taken from the Papua New Guinea Community Schools Mathematics Syllabus', 1978 .

No. 4: A.J. BISHOP 'Developing Spatial Abilities', 1977 .

No. 5: A. EDWARDS 'A Study of the Issues Involved in Establishing the Mathematics Education Centre and a Report on its Work from December 1978 to May 1979', 1979 .

No. 6: A. EDWARDS and A. RAJPAI 'Preliminary Report on the Basic Arithmetic Test Carried out in Post-Secondary Institutions in Papua New Guinea in 1979', 1979 (out of print).

No. 7: A. EDWARDS 'Final Report on the Establishment of the Mathematics Education Centre', 1979 (out of print).

No. 8: G.A. LEAN 'The Training of Spatial Abilities: A Bibliograph', 1980 .

No. 9: G.A. LEAN 'An Investigation of Spatial Ability Among Papua New Guinea Students', 1980 .

No. 10: G.A. LEAN and M.A. CLEMENTS 'Spatial Ability, Visual Imagery and Mathematical Performance', 1980 .

No. 11: P.L. JONES 'The Introductory Mathematics Programme at the Papua New Guinea University of Technology - A Survey of Student Opinion', 1980.

No. 12: P.L. JONES 'A Study of Proportional Reasoning', 1980.

No. 13: M.A. CLEMENTS and G.A. LEAN 'Influences on Mathematical Learning in Papua New Guinea: Some Cross - Cultural Perspectives' 1981, revised .

No. 14: M.A. CLEMENTS 'Careless Errors Made by Sixth-Grade Children on Written Mathematical Tasks', 1980 .

No. 15: P. SULLIVAN 'The Standards Debate: An Alternate Strategy', 1981 .

No. 16: P.L. JONES 'Mathematical Language and the Learning of Mathematics in Papua New Guinea', 1981.

No. 17: F. AUSBURN and L. AUSBURN 'Perception, Imagery and Education in Developing Countries', 1981.

No. 18: M.A.Clements and P.L.Jones 'The Education of Atawe',1981.

The following M.E.C. Technical Reports have been published:

No. 1: P.Sullivan 'Report of the First Conference to Prepare Mathematics Materials for Post-Secondary Courses',1981.

Other publications include:

C.Meek and P.Sullivan 'Games of Mathematics and Logic' (K1.00)
E.Wong and P.Jones 'Pharmacology and Drug Dosage Calculations' (K2.50)
P.Sullivan 'An Introduction to Nursing Mathematics' (K1.50)